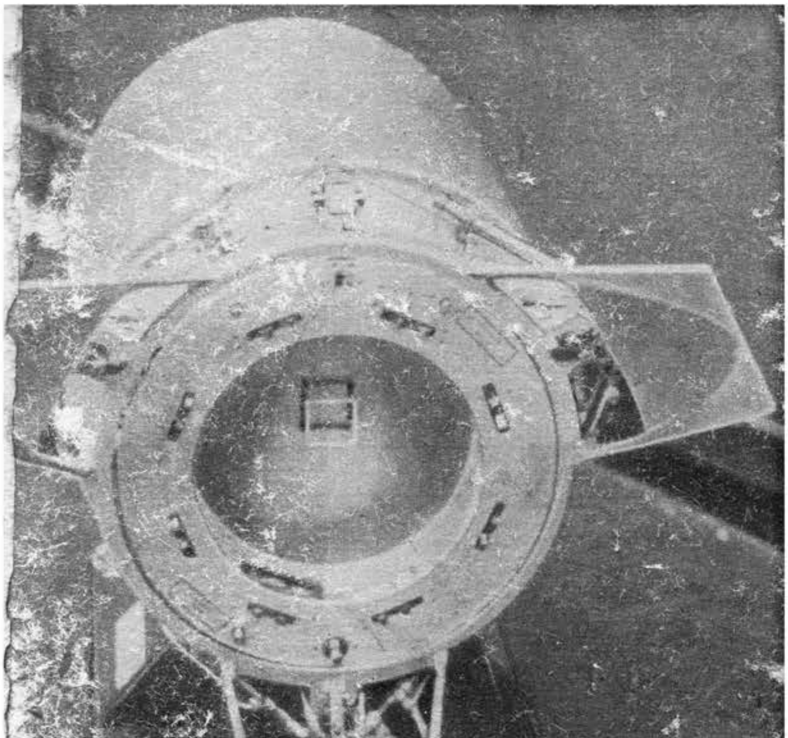
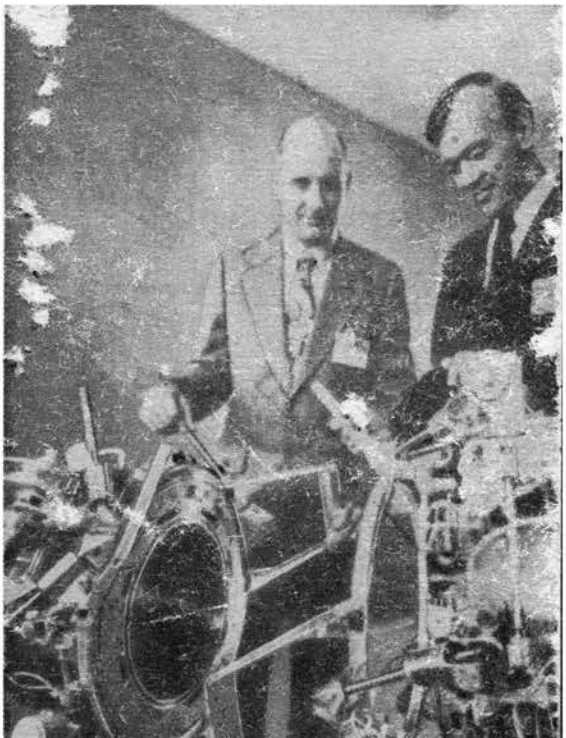
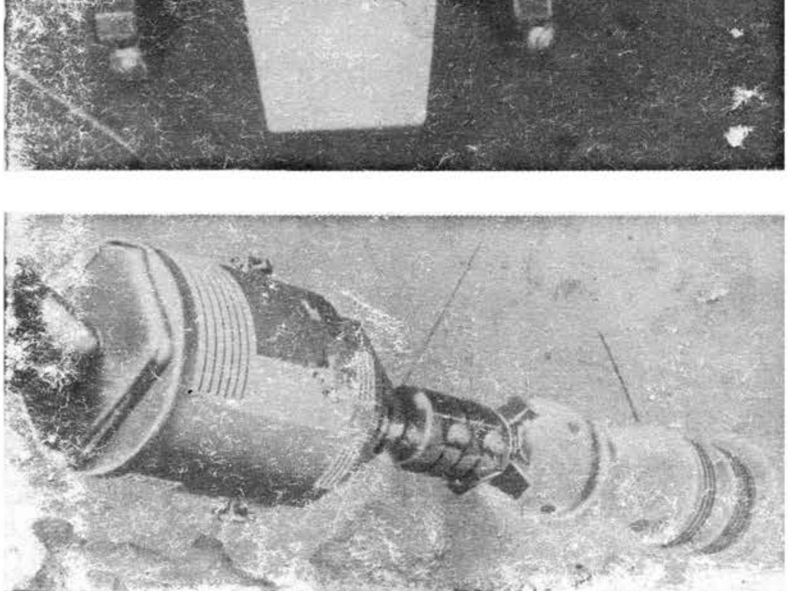
SPACEFLIGHT

88905 КОСМИЧЕСКИЕ ПОЛЕТЫ № Т-1
(спейсфлайт)
По подписке 1973 г.

olume 15 No. 1 January 1973







Published by The British Interplanetary Sc

SPACEFLIGHT

A Publication of The British Interplanetary Society

VOLUME 15 NO 1 JANUARY 1973 *Published 15 Dec. 1972*

Editor:
Kenneth W. Gatland, FRAS, FBIS

Assistant Editor:
L. J. Carter, ACIS, FBIS

CONTENTS

COVER

TOGETHER IN SPACE. A major experiment in space collaboration will be made between the United States and the Soviet Union in July 1975 when an Apollo CSM launched from the Kennedy Space Center docks in Earth-orbit with a Soyuz spacecraft launched from the Baikonur cosmodrome (*Spaceflight* November 1972 pp. 402-406). To achieve this both the U.S. and the Soviet spacecraft have to be made compatible, and the Apollo will carry a special docking module to allow men to pass between the 2 ships. These pictures show the progress which has been made to date. *Top left*, 1/5th scale working model of docking module by NASA. *Right*, astronaut Thomas Stafford and cosmonaut Alexei Yeliseyev (right) examine a Soviet-built model of the Apollo-Soyuz docking unit during a recent Moscow Conference. U.S. and Soviet designers have made the docking units identical for each side so that either ship can take the active docking role. *Bottom*, scale model of 2 spacecraft in the docked configuration. Space crews begin joint training for the mission in the second half of this year.

Jacques Tiziou/Novosti Press Agency

MILESTONES

Oct

17 Mitsubishi Heavy Industries announce that NAR MB-3 engine developed for U.S. Thor will be built under licence; 3 engines will power first stage of Japan's new N-type launchers. N-1 vehicle will have Japanese-developed, pressure-fed, storable propellent, second stage and Japanese solid-propellent third stage. Engine test facility to be built near launch site on Tanegashima island.

17 U.S. astronaut Thomas Stafford visits Zvezdny Gorodok (Stellar Town) near Moscow where Soviet cosmonauts live and train; tries out Soyuz docking simulator with Andrian Nikolayev and Vladminir Shatalov.

18 Committee of alternates in Paris fails to find common agreement to merit full European Space Conference scheduled 27-28 October. West Germany recommends holding meetings in two parts, first on 8-9 November and full ESC at unspecified date before end of year. Conference, originally deferred from 11-12 July, to decide whether Europe will join Post-Apollo (now essentially manned sortie laboratory for space shuttle), and future of Europa II and III.

27 Mariner 9 completes programme in orbit around Mars after attitude-control nitrogen gas becomes exhausted. Transmitted total of 7,329 pictures since entering orbit 13 November 1971, but last 15 pictures taken before nitrogen was depleted could not be transmitted.

Nov

2 B.I.S. Statement addressed to Prime Minister repeats urgent need to establish United Kingdom Space Authority to stimulate and co-ordinate activity (see pages 34-36).

8 Mr. Michael Heseltine, UK Minister for Aerospace, at Paris meeting of science ministers represented in European Space Conference, urges creation of European space agency to achieve common policy as a pre-equisite for participation in Post-Apollo. (A similar recommendation was made to the UK Government by the British Interplanetary Society on 1 February 1972 (see *Spaceflight* April 1972 pp. 126-127). Under Heseltine proposal individual countries would be free to choose projects and level of financial commitment (e.g., scientific satellites, applications satellites, post-Apollo sortie module, etc.) and participation in agency would not be on a basis of G.N.P. Ministers to respond at European Space Conference to be held in Brussels in December.

9 NASA launches Canadian domestic communications satellite Telesat-1 ('Anik') by Delta 92 rocket from Kennedy Space Center for positioning at 109°W longitude (south of Gallup, New Mexico). Geo-stationary satellite will accommodate 10 colour TV channels or up to 9,600 telephone calls to link thinly-populated northern territories.

11 Apollo 17 astronauts announce names of their spacecraft: command ship is 'America' and lunar module is 'Challenger'.

SPACE IN THE 1980's*

By Dr. Wernher von Braun

After a career in rocketry and astronautics which spans more than 40 years – from the pioneer experiments of the German VfR to Saturn V – Dr. Wernher von Braun, 60, retired as Deputy Associate Director for Planning of the National Aeronautics and Space Administration last summer (*Spaceflight*, September 1972 p.344). NASA he said had sufficient well thought out plans for many years to come and he now wished to devote his time to help implement some space projects which he believes will have particular importance.

In his new post as Corporate Vice-President for Engineering and Development of Fairchild Industries, Dr. von Braun will be directly concerned with the ATS-F and ATS-G satellites which are to test many Earth-related applications including an experiment to use direct-broadcasting techniques to spread basic education in the Third World. We asked Dr. von Braun – an Honorary Fellow of the B.I.S. – to discuss these and other space applications which he felt would have far-reaching importance as we look towards the end of the 20th century.

Kenneth W. Gatland

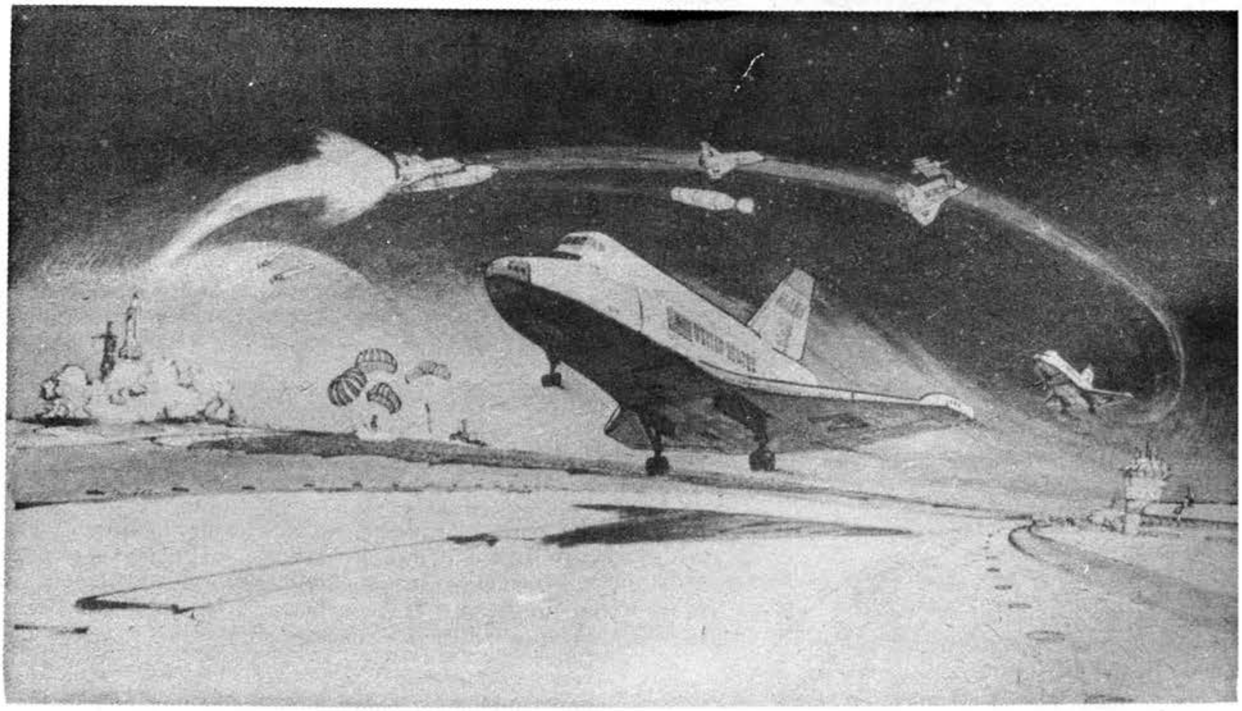
The Shuttle

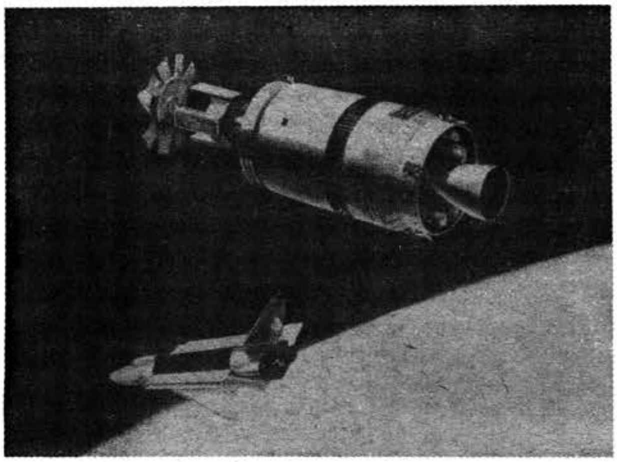
The Shuttle is a 2-stage re-usable vehicle that will begin operations before the end of this decade to serve a broad range of functions. First, it will provide a versatile capability for the economic transport of spacecraft to low Earth orbit in preparation for their subsequent transfer by a Space Tug into the desired orbit or escape trajectory. The Shuttle will also be able to return spacecraft from orbit to the Earth for repair, refurbishment, and reuse. In addition, the Shuttle will place large telescope and observatory modules in orbit and revisit them periodically to change experiments, retrieve data, and service the modules. The Shuttle will be used to house within its cargo compartment a variety of experiment modules that provide a laboratory environment and living accommodations where specialists can conduct scientific and technological observations and experiments in Earth orbit on brief 'sorties' for periods extending from several days to a week or more. Finally, it will have the capability of transporting Space Station modular elements into orbit and of providing logistic support to the assembled Space Station. Utilization of the Shuttle for operations such as these will permit an entirely new approach to the design and development of spacecraft and experiments to take advantage of the opportunity for on-orbit checkout and activation, repair and refurbishment, relaxation of weight and volume constraints, and simplified manned on-orbit operations. This new capability and approach to system development will allow the introduction of a new and more productive era of space activities without commensurate increases in investment.

The Space Tug

The Space Tug, mentioned above, is a propulsive stage capable of being carried into orbit in the Space Shuttle cargo bay. Once in orbit it will have the capability of performing missions ranging from placing spacecraft into orbits only slightly different from that of the Shuttle to the injection of spacecraft into geosynchronous orbit or on escape trajectories. Although the ultimate performance objectives for this propulsive stage include manned applications, spacecraft retrieval, and reuseability of the propulsive stage itself, the early capability may be somewhat more restricted.

Based on a paper 'Benefits from Space Applications in the 80's' presented at a recent Symposium of the American Astronautical Society.





Space tugs can operate in near-Earth orbit out to geo-stationary orbit. They can also inject payloads delivered by the space shuttle into interplanetary trajectories.

North American Rockwell

The Sortie Module

A Sortie Module, which will house and support specialists while they conduct short duration experiments or observations in Earth orbit, is planned for development to support operations beginning as soon as the Shuttle becomes operational. During early missions this module will remain connected to the Shuttle and will contain living accommodations that are adequate for several experimenters for the relatively short time that they will be in orbit. It will also provide the necessary power supply, experiment racks, and observation ports for their experiments. The mode of operation and the support of the experimenters' activities will be patterned after NASA's very successful and economical airborne research programme using current jet aircraft. The Sortie Module will therefore be a reusable space laboratory that economically supports scientific and applications experiments and observations to extend, support, and augment the capability of the various Earth orbiting spacecraft and observatories. These modules can be provided to experimenters, in the United States and in other countries, for outfitting and for use in space during the period required for their experiments. Studies are being made to examine the feasibility of equipping the Sortie Module with the additional systems which would be required to permit its separation from the Shuttle and independent operation for periods up to one month. Such a module could also be used subsequently in conjunction with a Space Station. This added capability, although limited in duration, would significantly extend the scope of operations which are opened by the introduction of the Shuttle.

Technology Advances

Adding to our capability of the future will be the advances and progress made in technology. It is certainly reasonable to expect that during the 70's great strides will be made in many technological areas, to cite a few examples: sensors and instrumentation, micro-electronics, antennae, space power, data transmission, propulsion, and life support systems. These advances will provide a strong technological base for our future operational systems. Through utilization of the capabilities described above, the Shuttle and its related major systems will be able to serve many government organizations. They will, in addition, inherently operate effectively with space systems developed by other nations and can therefore be used by the international community. Thus, these new space capabilities will provide an important added opportunity for international co-operation through joint participation in space activities.

Let us now raise our sights from the decade of the 1970's to that of the 1980's, and attempt to foresee (within our human limitations) how our space capability, which I view as a national asset, can benefit man on Earth. We will begin by examining the demands man places on his environment and identify some of the problems that beset him.

Man's Environment

From the soil of the Earth man obtains the many varied crops to feed himself, his herds of sheep and cattle feed upon the grazing lands, and the forests provide the basic element for a multitude of wood products. From beneath the Earth he extracts the gas, oil and coal to meet his energy requirements, and he extracts the minerals and ores for refinement into chemicals and metals. He builds reservoirs to conserve his drinking water, dams the rivers to obtain hydro-electric power, and takes great quantities of fish from the oceans. And finally, he looks to the land and seas for his recreational activities.

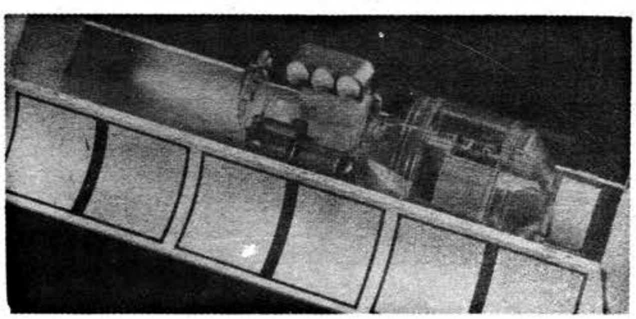
Natural Problems

But all is not serene for man on Earth. Periodically man is plagued by the great forces of nature that manifest themselves in one form or another to wreak havoc on his environment, destroy his home, and threaten his very life. We are all too familiar with the massive destruction and tragic loss of life that can result from hurricanes, tornadoes, floods and earthquakes. Mother Nature may also decide to demonstrate her versatility by volcanic eruptions, unleashing massive tidal waves, or having protracted periods of drought. And let us not forget, in the aftermath of these cataclysmic events, man may have to fight disease and sickness before he can face the task of rebuilding.

Man-Made Problems

Nature is not alone in creating problems; man seems to be doing a pretty good job of creating some himself. Today we

In this model the sortie laboratory 26 ft. long by 14 ft. diameter is shown in the cargo bay of the shuttle. It comprises a pressurized unit for up to 4 scientists (right) and an attached instrument pallet.



are all concerned with the smog that hangs over many of our cities; the effluents that come out of the smokestacks; and the chemicals and sewerage we dump into our lakes and rivers. Our transportation systems are choked by congestion and, through carelessness, we burn thousands of acres of valuable timber. Additionally, we are faced with the need to feed a growing population and to meet the increasing demand for energy, indicating a definite requirement for more efficient and productive utilization of our available land and resources. No doubt these natural and man-generated problems, in varying degrees, will still be with us in the 80's and I feel that our space capability can play an important role in our efforts to minimize the impact of these problems and in improving the quality of life on Earth.

Aid to Solution

Of primary importance is to direct our national capability and technology toward areas of greatest significance, such as: surveying the resources of the Earth; weather observations and predictions; expanded communications; and improved navigation and traffic control. Let us first address ourselves to the key areas of Earth resources and meteorology and then, later, to communications and navigation.

Integrated Earth Survey System

An integrated Earth survey system, including Earth resources and meteorology, can play a significant role in ameliorating many of man's problems. The basic elements of such a system would include:

(a) The Observation element wherein much needed data on the environment would be obtained. This element would employ the optimal combination of ground, aircraft and spacecraft systems, capitalizing on the major capabilities for which each is best suited.
(b) The Data element wherein interrelated physical models of the Earth and its environment would be continually updated with the observational data.
(c) The Utilization element providing accurate and timely information and predictions on which decisions can be based in the various sectors of human endeavour.

The technologies for these elements are available or underway, and if we turn to the task, we should be able to develop an integrated capability that would gather environmental data on a global scale, transmit this data quickly and accurately to the data element, and with a meaningful level of predictability as an output, decisions could be made as to the optimal course of action.

Potential International Benefits

The application of this capability would be useful to many domains; the public sector, the commercial sector, and the international sector. Within the international arena the types of benefits that can be foreseen are:

(a) Co-operative and co-ordinated weather modification and climate control actions.

OLYMPIA, SEATTLE, TAKOMA. This is a reproduction of a colour composite photograph from the Earth Resources Technology Satellite (ERTS) 1 received and processed at NASA's Goddard Space Flight Center, Greenbelt, Maryland. Three colours, green, red and infrared seen and recorded separately by the satellite are combined. Healthy crops, trees, and other green plants which are very bright in the infrared but invisible to the human eye, appear as bright red; barren land, cities and industrial areas appear green or grey. Clear water is completely black and snow or ice show as bright white. Major geographical landmarks are: Puget Sound (upper centre); city of Olympia (lower centre, tip of Puget Sound); city of Seattle (centre, slightly left of Lake Washington); city of Takoma (centre, to right of lake Washington); snow covered Mount Rainier (lower right), Cascade Mountains (upper right) and mountain ranges of Olympia National Park (extreme left). Picture was taken 28 July 1972 from an altitude of 915 km.

National Aeronautics and Space Administration.

(b) Natural resource conservation agreements.
(c) Natural disaster warning and avoidance.
(d) World food planning and allocation.
(e) Co-ordinated search and rescue operations.

If these can be attained, then indeed, great strides will have been made in improving the quality of life on Earth.

There are many interrelated areas which can benefit from observations made of the Earth, but within the limited space available, I will only highlight some of the key benefits that can be attained.

Agriculture and Forestry

Our ever-growing world population dictates the need to increase our food production. Toward this end the data obtained from an Earth survey system would be extremely useful. Of primary interest would be periodic crop inventory which would lead to the identification of crop types, the acreage that has been planted, and the state of growth. Actual and potential damage to crops through disease, insects, and drought would be rapidly detected, permitting corrective action to be taken. With this information future yields of world food production could be predicted, thus permitting improved planning, management and distribution of food supply.

More efficient land use could be obtained through the identification of unused land that is capable of supporting crop growth. Deficiencies in the soil of used and unused land could be detected and corrected to increase crop yields, and irrigation requirements could be defined more accurately. Animal and grazing land inventories could be correlated to maintain a balance between livestock feeding requirements and the amount of grazing land available.

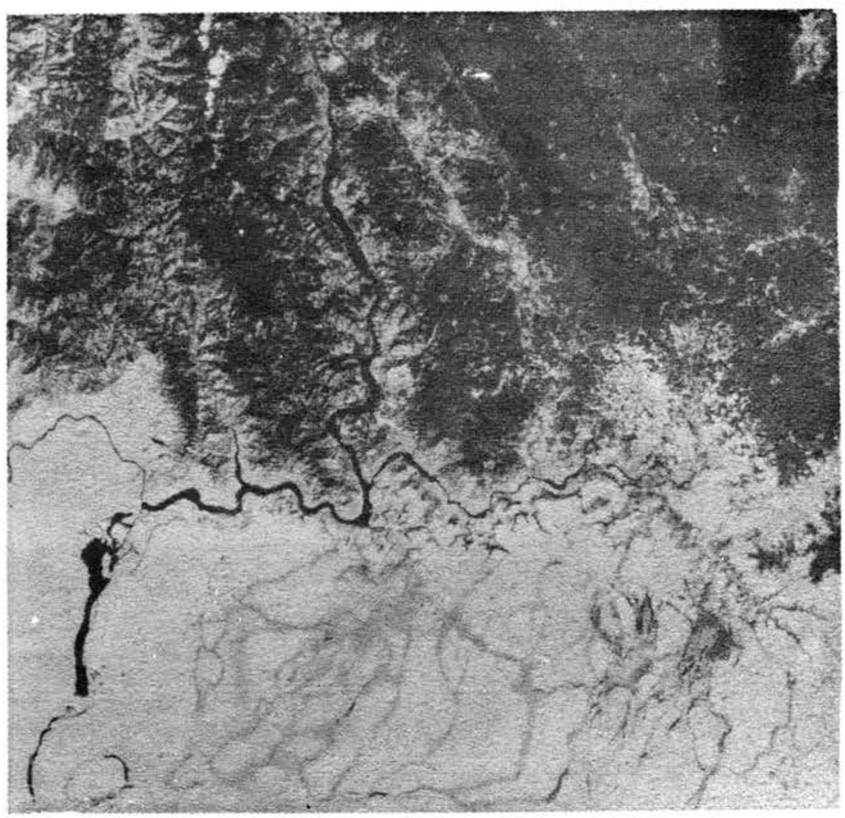
Forestry

Monitoring and assessing the status of our forestry would require information similar in nature to that obtained for agriculture. Census data will provide the quantities involved, the types of trees in growth, and their readiness for cutting. Through remote sensing the detection of disease can be accomplished on a large scale basis, permitting early remedial steps to be taken to conserve this valuable resource. And here again, additional land capable of supporting tree growth could be identified and put to use.

Geology and Mineral Resources

Man employs a variety of the Earth's natural resources in vast quantities. The spectrum of use includes gas, oil, and coal for energy; metals and chemicals for industrial purposes; and stone, gravel and sand for construction. Continued use of these resources on a growing scale can be abetted by an Earth survey system.

Observations of the Earth will provide data on surface features and characteristics. Analysis and interpretation of this data by geologists will permit the development of significantly improved geologic maps of major structures and topographic elements. Assessment can be made of the available mineral resources, rate of use, as well as prediction



SPOKANE, WASHINGTON. This black and white photo was made from ERTS-1, Band 5. The area shown is about 34,000 km^2. The Columbia River can be seen flowing from the top to the bottom in the left centre of the photo. Grand Coulee Dam is in the left centre. The Spokane River extends through the right centre with the city of Spokane at the extreme right at the head of the river. Dry fields in the plains area (lower half of photo) can be recognised by lighter shades. Darker streaks in this area indicate moisture along streams and rivers. The darker shades in the upper half of the picture are the mountains of the Kettle River Range. Photo was taken on 26 July 1972 from an altitude of 915 km.

National Aeronautics and Space Administration.

of possible location of new sources of gas, oil, and minerals.

Continuous surveys can provide updated information on varying geothermal conditions, as well as glacial and volcanic activity. Accurate mapping of fault structures, coupled with improved predictions capability, provide early warning as to time and location of impending Earth tremors. The attainment of such a capability certainly could contribute to the saving of many lives.

Hydrology and Water Resources

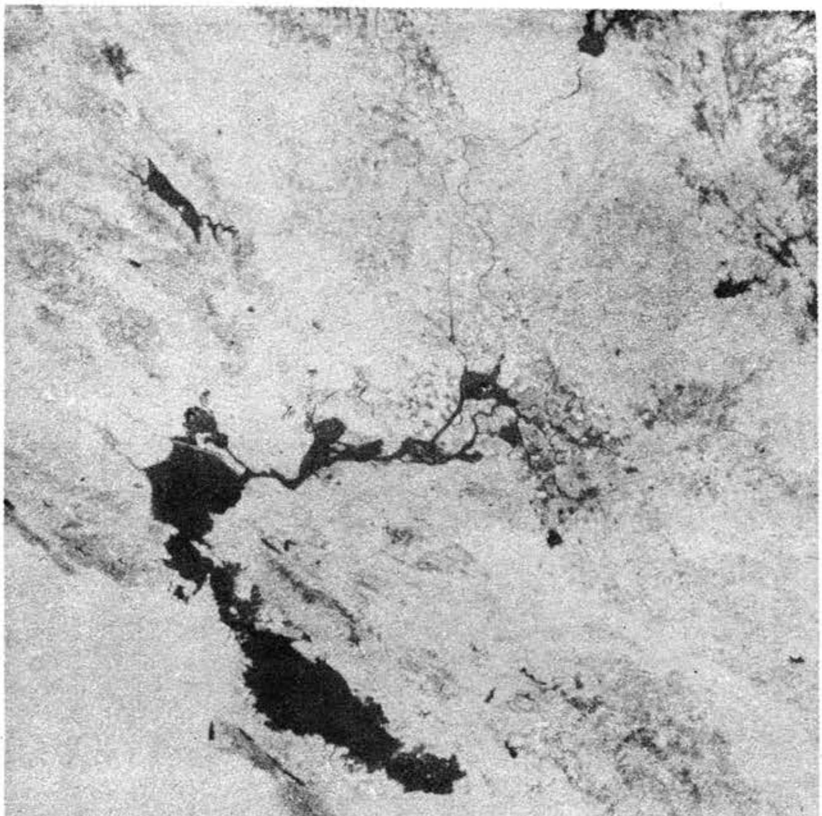
The growth of food, vegetation and forests, and the ability to sustain animal and human life, requires an adequate supply of that precious commodity – water. There is valid concern about our declining water tables and our present-day search for new sources is typified by our experiments to convert sea water on an economical basis. Our survey systems of the future can play a significant role in man's efforts to conserve and manage the available water supply, and in his search for new sources.

Measurements of the location and amount of rainfall, snow and ice can be used to forecast the amount of run-off. Untapped sources, such as fresh water flowing into the oceans, can be accurately identified. With this information, the siting of new wells and reservoirs can be planned and implemented for maximum utilization of the water supply. Periodic monitoring of the status and condition of the many lakes and reservoirs, correlated with the anticipated water in-flow, will provide improved water control and management. Efforts to preserve the quality of fresh water would be enhanced by the remote sensing of pollutants entering the water supply. With early and accurate detection of the offending source, determination can be made as to the appropriate course of action to maintain the quality of the water.

Data obtained would provide valuable information on the condition of our major rivers and streams. Determination could be made of the erosion damage due to river flow, the extent and magnitude of industrial pollution, and the impact of sea water back-flow. Early warnings would be issued to residents of areas wherein dangerously high water levels or flood conditions are expected.

Oceanography and Marine Resources

Our systems capability of the 80's can certainly be applied to provide man useful data on the environment of the seas and its resources. Satellite information, in conjunction with aircraft and surface measurements, would result in the accurate mapping of sea temperatures, sea state conditions, location of upwellings, and ocean current flows. This knowledge can be used to reliably predict the location of fish thereby increasing our food production from the sea. The data would also provide improved definition of coastal regions and tidewater lands; the confluence of rivers and the ocean, and the nature of the related sedimentary flow. Monitoring of the colder regions of the oceans would give the location and movement of icebergs and ice floes; advisories and iceberg warnings would be issued; and vessels would be rerouted to safer shipping lanes. Determination could be made of the best lanes for icebreaking operations.



SAN FRANCISCO. In this reproduction of a colour composite photograph received from ERTS-1 on 25 July 1972, several notable geographical features appear: San Francisco Bay (lower centre); San Jose (bottom centre); Tomales Bay (far left); foothills of Sierra Nevada (upper right); Sacramento Feather River system emptying into the Bay (slightly right of centre); Lake Berryeses (centre); San Francisco International Airport (lower centre); fog rolling into Bay (lower left corner), and sediment in both bays (lower left).

National Aeronautics and Space Administration.

Meteorology

The processes of weather impact on man and his daily activities in many ways. On any given day our continent can experience a wide variety of climatic conditions. On 17 August 1969 there was a snow storm in Alaska, the Pacific Northwest had rain, and the Southern California coast was blanketed by fog. The Northern Plains were experiencing thunderstorms, while further to the south in Texas fair weather prevailed. Electrical storms were harassing the Northeast, tornadoes struck in the Southeast, and hurricane Camille was ominously approaching the Mississippi coast. Certainly we can derive significant benefits if we can develop a better understanding of these weather processes and a higher level of knowledge of global weather conditions. This will provide the basis to develop a long-range prediction capability and possibly the means for eventual control of the weather.

The application of space technology, with the ability to obtain global weather information from space, can play a significant role in a complete system for global observation of the atmosphere. Our present-day NOAA operational satellites, the Nimbus-class experimental satellites and manned flight experiments, are already demonstrating the capability to obtain images of global cloud cover; quantitative measurements of the atmospheric structure; and information on the formation, track, and dissipation of major storms.

The results from our present efforts will provide the core of our future global system, which would tie together the data from the space segment with the data obtained from ground sounding stations, and sensor-equipped balloons, buoys and other platforms. Comprehensive atmospheric models, developed from analytical studies and measurements performed in the 70's, would be computerized. In conjunction with the data obtained from the observational system, a continuous description of the atmosphere and long-range predictions, in the order of 14 days, would be provided. Let me highlight a few of the benefits that would accrue from such a capability.

Natural Disasters

Long range predictions of impending hurricanes, tornadoes and floods would permit the implementation of evacuation procedures or other preventative actions to minimize loss of life and damage to property. Preparations can be made early for post-disaster action, such as assessment of damage and rescue and relief operations.

Agriculture

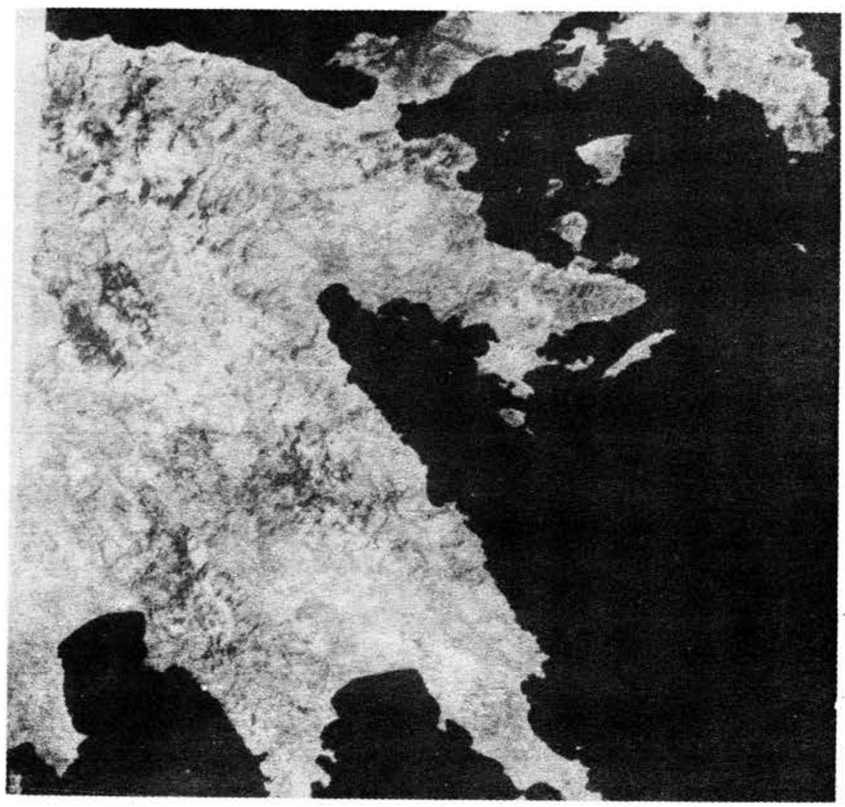
Scheduling of seeding, fertilizing and spraying operations could be optimized. Timing of the harvesting of crops could be adjusted to minimize loss due to damaging weather conditions.

Transportation

The various transportation modes: air, sea and land, would attain more efficient operations through improved scheduling and routing.

Commerce

Shipment of perishable commodities could be more



GREECE. Reproduction of a colour composite ERTS-1 photograph illustrates an area which is geologically complex and has frequent earthquakes. Many faults and folds are visible in the Peloponnesos at left, trending from upper left to lower right. Land is used chiefly for grazing and agriculture. Other geographical landmarks are: Athens (extreme upper right); Gulf of Corinth (upper left); Gulf of Messoni (extreme lower left); Gulf of Laconia (bottom centre); Sea of Crete (dark area, right side of photo); and Corinth Canal (top centre). Photo was taken from an altitude of 915 km on 2 August 1972.

National Aeronautics and Space Administration

effectively planned and scheduled. Spoilage losses due to delays in transit or at terminal facilities caused by inclement weather conditions, could be minimized.

Construction

Construction operations could be adjusted in conjunction with anticipated weather conditions, and the proper mix of the work force, materials, and equipment at the construction site,could be more efficiently scheduled.

Recreation

Improved planning of individual, family, and group recreational activities.

International Co-operative Efforts

Recognition of the potential and the benefits to be derived from meteorological systems has resulted in co-operative efforts between nations. An early step in this direction was the establishment of a bilateral Washington-Moscow circuit for the exchange of meteorological data. Both nations commenced transmittal of conventional data in 1964; the transmission of satellite data began in 1966, and this exchange is still continuing.

Directly related to future meteorological systems is the Global Atmospheric Research Program (GARP). This is an international research programme with the ultimate objective of attaining economically-useful long-range predictions. It seeks to achieve a better scientific understanding of the physical and dynamic processes of the atmosphere for incorporation into prediction models. It is a key step in man's continual efforts to accurately predict weather conditions and to eventually be able to modify these to his advantage. This programme is in its early phases and present efforts are directed at determining those nations interested in participating and their degree of participation.

Weather Modification

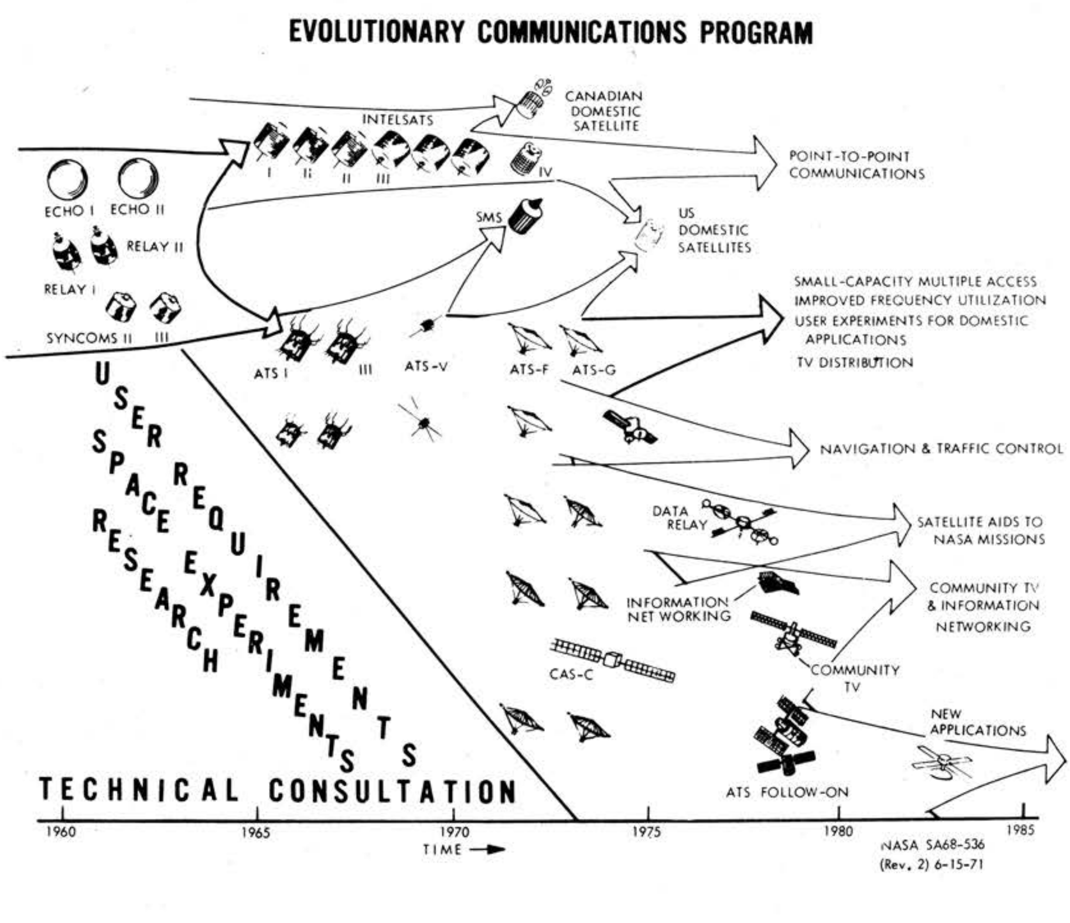
On a longer range basis, one of the major benefits to be derived should ultimately stem from our ability to utilize the information and predictions to actually modify or manage our environment. Preliminary weather modification experiments, on hemispheric scale, could be underway during the 80's. Such experiments would be a necessary step in learning how to manage the total climatic environment.

Communications

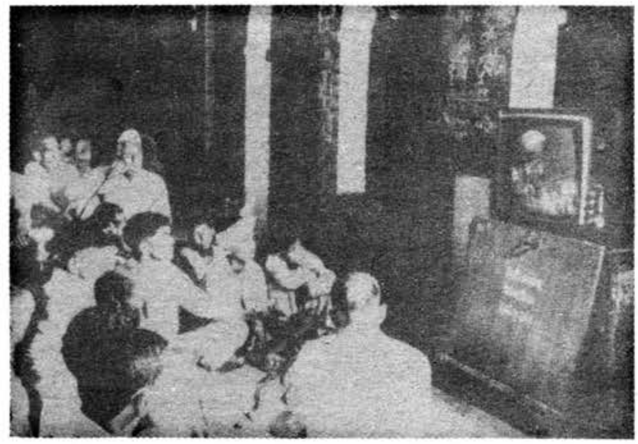
Let us now turn our attention from Earth observations to communications. The application of space technology to the field of communications has been clearly demonstrated. Increasingly, greater use is being made of satellite systems to relay voice, TV, and data from continent-to-continent. These systems are the predecessors to future systems that

This chart shows the rapid growth in space-relayed communications since 1960. To the right are new applications such as community TV and navigation and traffic control (marine and aeronautical) in the advanced planning stage.

National Aeronautics and Space Administration

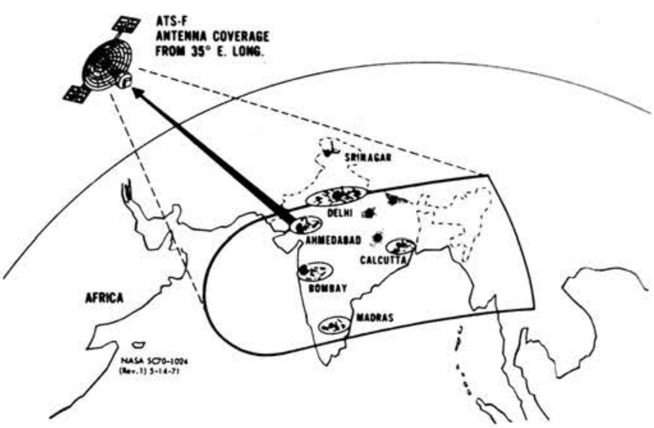


can provide new and better services to meet the needs of our expanding population and the demands for greater exchange of information.



Programme Evolution

Examination of the orderly progression of our communications programme perhaps can indicate what is in store for us in the 80's. The research and operational experiments that we performed in the past provided the groundwork for the present international commercial communications satellite system. Other operational capabilities will result from our current and planned programme. Future needs are identified through our advanced studies and critical technologies developed by our technology development projects. During the 70's the Applications Technology Satellite (ATS) will be the primary vehicle for flight experiments. The continuing development of technology could lead, within the time frame of the 80's, to applications such as community TV, information networking, and even eventually direct-to-home broadcasting. The benefits to be derived from such future systems are many and diverse – let me cite a few of the more significant ones.



Education

Early experimental efforts in this field are characterised by the highly significant instructional TV experiment with India utilizing the Applications Technology Satellite (ATS-F) to be flown in 1973. The satellite will be used for transmission of instructional video from a station in Ahmadabad to a complex of about 5,000 receivers distributed over the entire country.

Large metropolitan areas and two-thousand villages, encompassing millions of people, will receive the TV. The satellite will provide one TV channel for 4 to 6 hours a day, with the government of India responsible for the programming. Instructional information on health, agriculture, education, and other important fields will be made available to this large population. Such experiments could be the precursor to bringing to the peoples of the world educational information on a highly economical basis and on a scale far greater than could be anticipated by conventional means.

Remote Areas

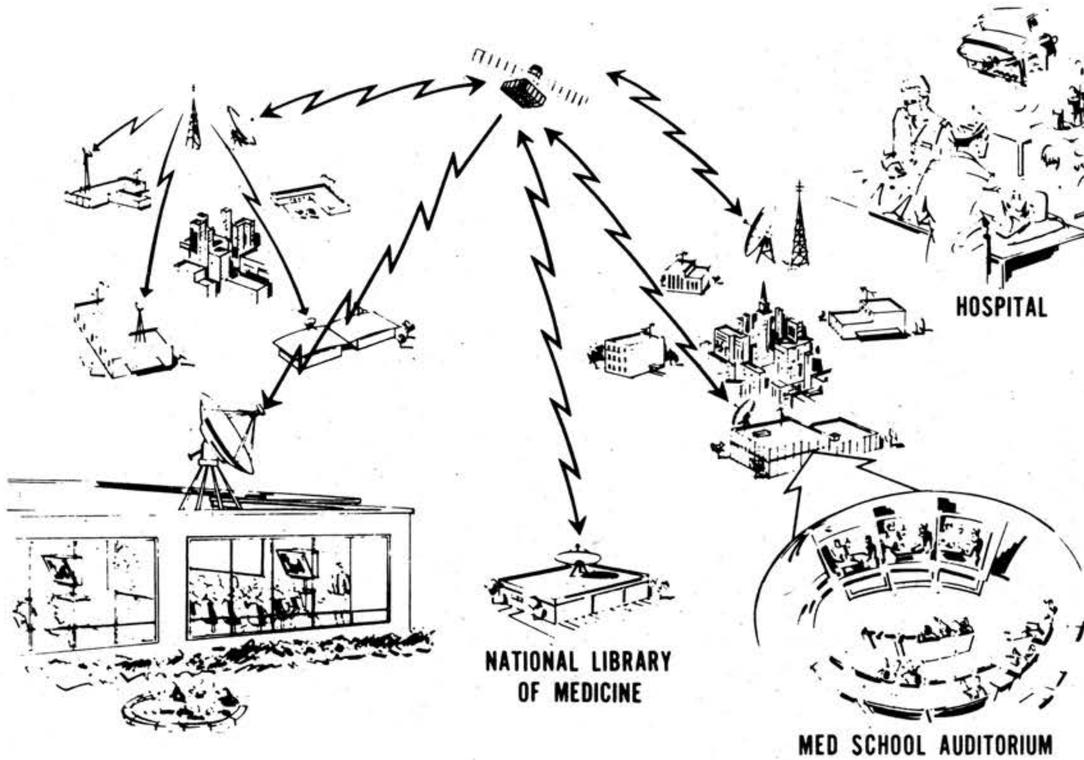
Space capability can provide the means for communicating with people living in remote parts of the world. Illustrative of this capability is the experiment with the State of Alaska for the use of TV and radio for instructional purposes utilizing the presently orbiting ATS-1 spacecraft. Video information from Fairbanks are relayed by the spacecraft to population concentrations (Ft. Yukon, Nome, Kodiak) and then redistributed to educational institutions. Radio transmissions from Fairbanks (not on a simultaneous basis with video) are relayed through the satellite to Anchorage and Juneau, and can also be received by small receivers distributed throughout the bush villages. This provides both instructional service and information contact to people who otherwise have no contact with the outside world.

Information Networks

Information networking is a potential application which would provide geographical coverage and interconnection to members of specialty groups for information exchange. The National Library of Medicine at the National Institutes of Health has been exploring the possibilities of setting up a biomedical communications network. The concept ultimately envisions real time interconnection of operating rooms with viewing auditoria, not only for instructional purposes, but for essentially realtime professional colloquia, and possibly even two-way televised consultation. This service could also be used to provide health education to schools and health information services, and provide practicing professionals access to conferences, special lectures, and case histories and records. Although in the embryo stage, with the role of satellites still being defined, it is apparent that the attainment of such a service would be of great value to the field of medicine with commensurate benefits to many people. Needless to say, other specialty groups such as Agriculture, Law Enforcement, and others could also derive benefits from the ability to exchange information on a greatly increased scale.

Transportation

Associated with our expanding society is the parallel growth of our transportation systems. The movement of



Conceptual Medical and Health Information Network.

National Aeronautics and Space Administration.

goods and people on a massive scale indicates a need for greatly improved navigation and traffic control. Our present efforts, being co-ordinated with other government agencies and international groups, could eventually lead to a global system with resulting benefits to the many forms of transportation.

Improved and reliable communications and position fixing capability for transoceanic air traffic could permit optimum aircraft spacing and lead to greater safety and efficiency of operations. Similar benefits could accrue to surface vessels plying the shipping lanes of the Atlantic and Pacific oceans. The ability of the global system to communicate and provide navigational information on an all-weather basis would permit continental and intercontinental traffic to determine their position in all forms of weather and to select their optimum routing.

With accurate knowledge of position, speed and direction, immediate steps can be taken to avoid collisions. In those events where a disaster has taken place, due to natural causes or otherwise, quick and accurate determination as to the location of the accident, particularly if located in remote areas of the world, would greatly abet search and rescue operations.

Other Benefits

By necessity, I made no effort to be all-inclusive in identifying the future potential benefits. In addition to those areas I have covered there are certainly others which will also derive benefits from our future space programme. Science would attain a higher level of knowledge of our Sun, Earth, sister planets, and the remote stars. This would lead to a greater understanding of our Earth and the Universe within which it resides, and possibly provide some additional clues in our search for the origin of life. The transfer of technology is certainly an asset we must consider. Research and experimentation in space, and in our ground laboratories, may point the way to new innovations, new materials, and improved processes and manufacturing techniques. These technologies could result in new materials, products and services applicable to the many sectors of life.

Need for Co-operative Effort

It is recognized that the ultimate attainment of many of the benefits I have defined does not alone lie in our capability to put systems together; indeed, there are a host political, social, legal and economic aspects that must be considered and resolved. If then, we are to achieve these benefits on a truly global scale, the co-operative effort of all participants, both national and international, must be forthcoming and directed at the many questions that must be answered.

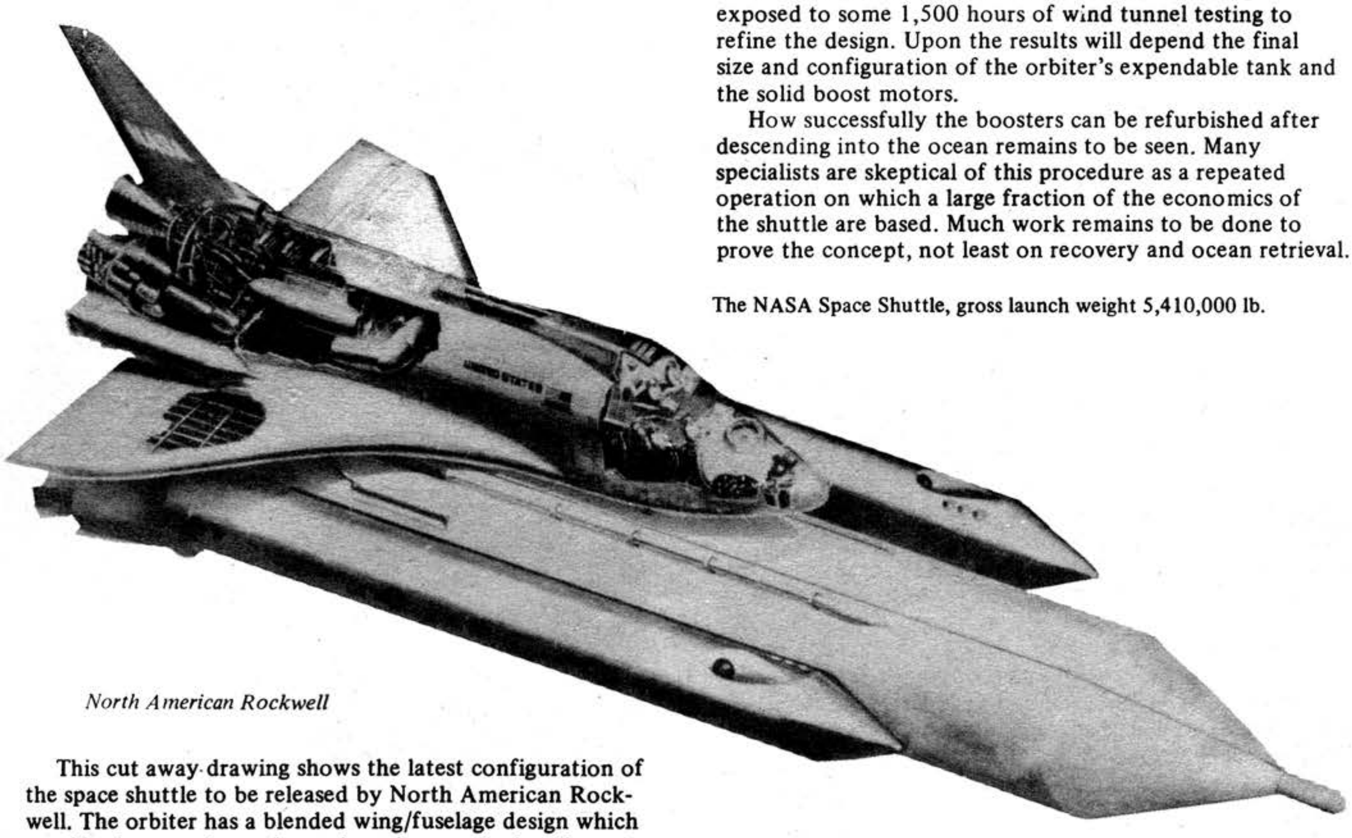
As we all know prognostication is a risky business, but I do feel strongly that the application of our space capability can play a significant role in providing a better quality of life to the peoples of the world. Let us avail ourselves of this opportunity.

NEXT MONTH

The February issue will include a special illustrated feature on the Skylab space station to be launched from the Kennedy Space Center on 30 April. Arrangements have been made, in conjunction with Transolar Travel Ltd., for a B.I.S. group to witness the double launch of the station and its first 3-man crew. The party leaves Gatwick Airport by Boeing 707. Further details are available from the Executive Secretary.

DESIGNING THE SPACE SHUTTLE

By Kenneth W. Gatland



North American Rockwell

Meanwhile, scale models of the shuttle are being exposed to some 1,500 hours of wind tunnel testing to refine the design. Upon the results will depend the final size and configuration of the orbiter's expendable tank and the solid boost motors.

How successfully the boosters can be refurbished after descending into the ocean remains to be seen. Many specialists are skeptical of this procedure as a repeated operation on which a large fraction of the economics of the shuttle are based. Much work remains to be done to prove the concept, not least on recovery and ocean retrieval.

The NASA Space Shuttle, gross launch weight 5,410,000 lb.

This cut away drawing shows the latest configuration of the space shuttle to be released by North American Rockwell. The orbiter has a blended wing/fuselage design which provides improved aerodynamic and manoeuvring characteristics.

The crew compartment is a double-deck design for pilot and co-pilot above and two cargo specialists below. Controls for the flight crew are duplicated. A fundamental change from the life support system in the Apollo spacecraft is that a full nitrogen/oxygen atmosphere will be provided at 14.7 p.s.i.a., making the system compatible with Soviet spacecraft.

Provisional specifications of the space shuttle are given in the table. In addition to the main propulsion system, attitude-control propulsion systems (ACPS) are in separate pods, one on each side of the aft fuselage. Forward attitude control propulsion systems are installed on hinged doors located on each side of the nose. The doors are opened during space flight and closed during ascent through the atmosphere and re-entry from orbit.

North American Rockwell have a great deal of preliminary work to do before the design can be finished and sub-contracts placed for major items. Design teams at Downey are working in conjunction with four partners – General Electric Company, who are concerned with thermal protection for the orbiter; Honeywell Incorporated, flight control systems; IBM, data management, and American Airlines, maintenance.

First elements of the design to be changed will be the flight deck and crew compartment resulting from a decision to move the docking port and airlock from the nose to the top of the crew compartment forward of the cargo bay doors. This will push the crew forward and may result in a smaller windshield with less drag.

Another significant feature is the massive external tank which the orbiter carries into orbit. This will contain a retro-rocket to permit re-entry over a remote ocean area. At 26.5 ft. diameter x 182 ft. long, this is virtually a stretched S-II stage minus engines. It represents a most lucrative contract as it is destroyed with each shuttle launching.

Design Considerations

'What we are attempting is to develop a design that meets all of NASA's basic requirements for a flexible, low-cost system', said Bastian Hello, Space Division vice president and programme manager. 'We definitely feel we will be able to design the orbiter with the use of state-of-the-art equipment and technology, and through innovations of our own to reduce production and operational costs, while enhancing system reliability and quality'.

The delta-winged spacecraft is about the size of a medium-range jetliner. Capable of flying up to 100 missions, it will transport a maximum payload of 65,000 lb. into Earth orbit and will travel an estimated 3,000,000 miles during a typical 7-day mission. A comparable-size jetliner travels approximately 31,000 miles in one week of operation.

The orbiter structure and outer skin primarily are made of aluminium alloy. Thermal protection consists of ceramic and elastomeric (rubber-like) reusable surface insulation, and a reinforced carbon-carbon composite for the nose and wing leading edges. All vital systems and equipment are located to permit ease of checkout and maintenance, to speed turnaround time between missions. The avionics

system will employ approximately 60% 'mature design' components – equipment either already proven or easily available.

Avionics

Shuttle avionics consist of 6 subsystems: guidance, navigation, and control (GN&C); data processing and software; communications; displays and controls; flight instrumentation; and electrical power distribution and control.

GN&C provides automatic and manual control of the shuttle's payload-carrying orbiter in all flight phases, and guidance commands for steering and displays for the crew. It also provides inertial navigation for orbital flight, rendezvous, approach, and landing.

Three duplicate GN&C independent systems and a backup assure the safety of the craft. This level of duplication is called fail-operational fail-safe. That means that failure of a critical item of equipment will still leave the system operational (that is, have no effect on the mission), and failure of a second item performing the same critical task will still leave the craft able to return safely to Earth. GN&C equipment is divided into 3 subsystems: aerodynamic stability augmentation, the primary GN&C, and the backup GN&C.

The basic aerodynamic stability of the orbiter is augmented by an aircraft-type system which uses body-mounted rate gyros, accelerometers, an air data computer, and deployable probes. Although automatic control of atmospheric flight and even landing is provided, there are side stick rotational controllers, rudder pedals, and trim controls to enable the crew to fly manually.

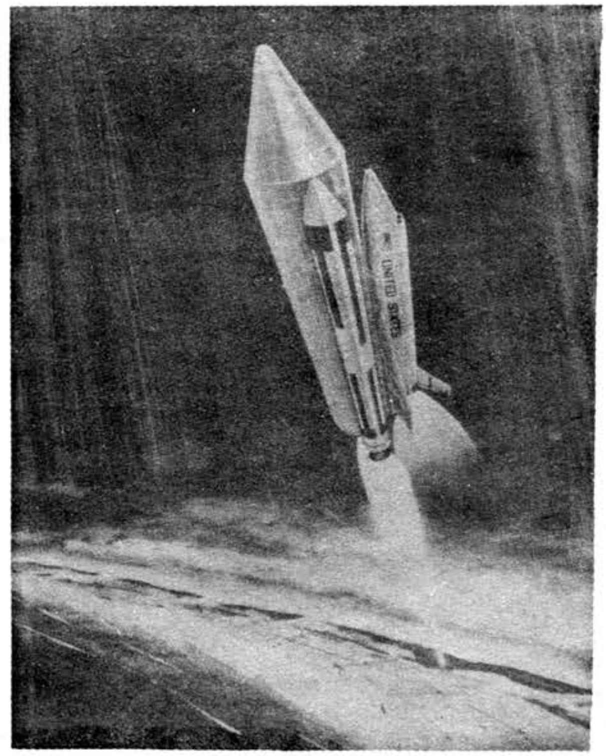
A feature of the Space Division design is the side-by-side control capability with relative simplicity so that either flight crewman may control and safely land the orbiter.

The primary GN&C has an inertial measurement unit similar to that used in Apollo and in many aircraft; horizon and star sensors, and such aids as TACAN (tactical air navigation, a radio frequency system which has wide military use), an instrument landing system, and a radar altimeter. All these items are currently in use in some form; some can be used in the shuttle without modification, while others require some degree of change.

Each of the 3 inertial measurement units, sensors, gyros, accelerometers, or other items feed information into the 3 primary GN&C computers. The computers – also a basically standard design – then generate the commands that control the orbiter and display the information for the crew. The backup GN&C is separate from the primary and uses completely independent sensors. Backup flight control is manual, based on information provided by the backup sensors and displayed in the cockpit.

The data processing and software subsystem is closely allied with GN&C. It involves the onboard digital computation required to support the primary and backup GN&C systems, to monitor performance of the vehicle, and to manage and handle the payload. Its hardware includes computers, mass memories, and input-output electronics.

The primary GN&C functions are mechanized in a high-speed, 64,000-word main memory, general purpose computer. The display, keyboard, and non-GN&C computation functions are mechanized in small computers of a single type augmented by mass memory. This approach satisfies redundancy requirements with low development and equipment costs. The GN&C computers are sized to allow for a 100% growth in memory, speed and input-output requirements, and the small computers are sized to allow for a 50% growth in main memory and 200% growth in main memory and 200% growth in mass memory requirements. In addition, the small computers have modular input-output circuitry to allow for future requirement growth.



Space Shuttle heads for orbit powered by a pair of large solid rockets burning in parallel with main engines of fly-back orbiter. The solids separate at an altitude of about 25 miles for recovery and re-use.

United Technology Corporation

The software (computer programme) will be designed so that a single baseline programme can accommodate all shuttle missions with rapid retargeting and reloading.

The communications subsystem takes advantage of both existing equipment space and aircraft communication networks. The system provides tracking, telemetry, command, and two-way voice between shuttle and ground stations; TV transmission to the ground as well as TV observation of the payload by the crew; two-way relay of voice and data from the payload (which may be manned or unmanned); navigation and tracking aids and communication equipment for aerodynamic flight and automatic landing; automatic antenna switching to assure coverage in all attitudes; and audio processing and distribution equipment.

The equipment is compatible with NASA, Air Force, and commercial air traffic facilities, does not require expansion or change in current space networks, and uses existing FAA and military aircraft facilities (augmented by 15-degree glide slope transmitters at landing sites). The subsystem utilizes S-band (for voice, TV, and telemetry, compatible with NASA and Air Force networks), C-band (for the radar altimeter), L-band (for the TACAN System and the Air Traffic Control network), VHF (voice), and

UHF/VHF (for the instrument landing system).

The displays and controls consist of the flight instruments, subsystem controls, and various displays, including the caution and warning system. The Space Division avoided the potential difficulty of providing dual controls (one set for space and another for air operation) by making the same basic controller serve for all mission phases (boost, orbit, entry, landing), using the same displays for different functions, and generally simplifying the cockpit arrangement and displays.

The flight-deck displays are grouped into 3 areas: two forward-facing flight stations (pilot and copilot), an aft-

NASA SPACE SHUTTLE

Prime contractor and integrator	North American Rockwell, Space Division, Downey, California.
Contract (R & D) orbiter and systems integration	$2,600 million.
Total project cost (R & D) – including orbiter, solid boosters, expendable tank, avionics, etc.	$5,150 million.

Space Shuttle System (all sizes and weights approximate)

Boosters — Two solid rocket motors, together with the orbiter's main engines, will power the orbiter from lift-off to staging altitude – about 25 miles. The solid rocket motors then will be jettisoned into the ocean and recovered for reuse. The motors will be 156 in. in diameter and 184.7 ft. long. Each will have an initial thrust of 4,130,000 lbf. reducing to 2,600,000 lbf. after 40 sec. to avoid overstressing the structure. Total burning time is about 117 sec. The motors are under the wings of the orbiter, attached one on each side of the orbiter's main propellent tank. Maybe replaced by 162 in. diameter boosters. (Contract has yet to be awarded).

Orbiter

Description — Delta-winged 125.7 ft. long and 55 ft. high, with 84 ft. wingspan. Has blended wing-fuselage design for optimum aerodynamic and manoeuvring characteristics. Structure features conventional aircraft design, and fabrication, basically utilizing aluminium alloy.

*External Propellent Tank** — Contains the liquid oxygen-liquid hydrogen main propellents for the orbiter. Aluminium alloy monocoque construction with urethane foam external insulation. Approximately 182 ft. long, 26.5 ft. in diameter. (The contract for the tank also will be awarded by NASA at a later date).

(Note: With external tank/solid rocket motors attached to orbiter, shuttle vehicle will be 202.7 ft. long and 74 ft. high).

Payload Bay — 15 ft. in diameter by 60 ft. long, has dual manipulator arms equipped with TV for deploying and retrieving one or more payloads. The payload bay will be environmentally-controlled.

Crew Compartment — The crew compartment houses the crew and has the 'brains' for operating and controlling the orbiter. The compartment has flight controls for the pilot and co-pilot and a double deck seating arrangement for the flight crew and 2 cargo-handling specialists.

Thermal Protection — The orbiter's vital thermal protection consists of ceramic and elastomeric (rubber-like) reuseable surface insulation, and a reinforced carbon-carbon composite for the nose and wing leading edges.

Main Propulsion — Three high-pressure, liquid oxygen/liquid hydrogen engines, each developing 470,000 lbf.of thrust in space, provide the main propulsion for the orbiter. The engines are being developed for NASA under separate contract by North American Rockwell's Rocketdyne Division.

Airbreathing Engines — Two airbreathing engines may be deployed from a compartment located in the orbiter's aft section for atmospheric flight following entry from a space mission, and 4 will be used for ferry missions and horizontal flight tests.

Orbit Manoeuvring Engines — Two 5,000 lbf. thrust engines will be used for the orbiter's orbit manoeuvring subsystem (OMS). The engines will be housed in pods and will be mounted in the aft section, near the main engines.

Reaction Control Engines — The orbiter's reaction control subsystem (RCS) will have two sets of 12 1,000-lbf. thrust engines located in the OMS pods in the aft fuselage, and two 8-thruster sets located forward on the nose.

Abort Motors — Two 386,000 lbf. thrust solid rocket motors to be mounted one on each side of the aft fuselage. (Maybe delected reducing shuttle's gross weight by about 7000 lbs).

Avionics — The avionics system consists of 6 subsystems: guidance, navigation and control (GN&C); data processing and software; communications; displays and controls; flight instrumentation, and electrical power distribution and control. Approximately 60% of the equipment for the over-all system will be of 'mature design', or those already proven or easily available.

Landing speed (orbiter)	175 knots (max).
First horizontal flight	1976, Edwards A.F.B., California.
First vertical launch,	1978, Kennedy Space Center, Florida.
Full operational capability	1980.

** This large tank can be compared with the second (S-II) stage of Saturn 5, minus engines. The S-II is 81.5 ft. long x 33 ft. diameter, weighs about 80,000 lb. empty and 1,025,000 lb. loaded.*

facing payload handling station, and an area for subsystem management and power distribution panels. A payload specialist station is located on a lower deck for management and checkout of payloads.

The instrumentation subsystem consists primarily of the sensors and associated electronics which monitor the condition and operation of vehicle systems. It provides the information that activates the caution and warning displays and includes the orbiter's master timing. Development flight instrumentation, a supplementary self-contained set of sensors and related equipment, will be used on early flights to aid evaluation of vehicle subsystems. After the development period it will be available to implement future mission requirements.

The electrical power distribution and control portion of the avionics consists of power conversion equipment and equipment for switching and distribution of ac and dc power.

In summary, the avionics for the shuttle consist mostly of existing equipment. Development problems are mostly those of modifying proven equipment; none are major.

Thermal Protection

Apollo astronauts were protected from the intense heat of re-entry (reaching 4,000 deg.F on the return from the Moon) by a heat shield which covered the module. Made of glass fibre honeycomb cells filled with a phenolic epoxy resin, the outer layer of the shield charred and melted, thus carrying the heat away from the module's stainless steel honeycomb structure.

This ablative system has worked well, and a lightweight ablator also could be used for the shuttle, but it has one drawback: it is used up during entry and so must be replaced, a time-consuming and relatively expensive process.

The orbiter must be refurbished quickly and inexpensively. It must be able to return to space after only 2 weeks. The thermal protection system is the key to this quick turnaround.

North American Rockwell's (NR) Space Division plans to solve the entry heating problem with a new system which saves weight, is easily refurbished, and will limit temperatures on the outside of the craft's aluminium alloy structure to no more than 350°F.

The system involves the use of 3 different elements on different parts of the orbiter. These are:

a) A low-weight elastomer (rubber-like material) that will be bonded to the 29% of the orbiter structure that does not experience ultra-high temperatures (less than 650°F).
b) A new ceramic insulation bonded to the 68% of orbiter surface that undergoes temperatures from 650 - 2500°F.
c) Another new material (oxidation-inhibited, reinforced carbon-carbon) for the wing leading edges and nose cap to withstand temperatures expected to exceed 2500°F.

The elastomer was selected for the 'low' temperature areas because it is lighter (3,500 lb. less than ceramic insulation for the same area), costs about a 10th as much to produce, and can be applied easily in relatively large (3 x 3 ft.) sheets.

The ceramic insulation has been under development for several years. It is built up in 4 layers:

a) A silicone elastomer adhesive.
b) A pad (from 0.3 to 1.5 in. thick) of chemically foamed methyl-phenyl silicone elastomer. This pad fills in surface irregularities, isolates the basic insulations from structural strain, and serves as a backup insulation.
c) The basic insulation, 0.5 to 2.0 in. thick panels made of Mullite fibres rigidized with a binder of aluminium-boria silica refractory glass.
d) A waterproof ceramic coating on the top and sides of the Mullite panels to protect them from weather and ground handling.

Although Mullite has been tentatively selected by the Space Division for the basic insulation, panels using silica fibres are also being developed and could be used if they prove superior.

The panels will vary in size from 8 - 20 in. square. Any panels showing heat damage from entry can be removed and replaced quickly and easily. Cracks and small holes can be temporarily repaired with silicone elastomer without removing the panel from the structure.

Small gaps (1/8th to 1/4th in.) will be left between panels to allow for heat expansion during entry. These gaps will be partly filled with a low-density quartz gasket to protect the structure.

The reinforced carbon-carbon (RCC) material is a carbon fibre-reinforced composite bonded with carbon. Also called pyrolized plastic, it is produced by high-temperature treatment of a resin-bonded laminate.

Although ablative material such as Apollo's could be used in the small areas experiencing ultra high temperatures without affecting the 14-day turnaround, RCC was picked by the Space Division because it is re-useable, less expensive, and lighter.

The ablative material also could be used in lower temperature areas if problems occurred in development of the ceramic insulation. Although the new material will be cheaper, lighter, and provide easier maintenance, the availability of the proven Apollo techniques means that development of the shuttle as a whole will not be delayed because of problems in developing the insulation.

BOOSTERS FOR THE SHUTTLE

Models on this page show something of the work which is being done to develop the large 156-in. solid-propellent boosters for the space shuttle. The twin motors which burn in parallel with the main engines of the winged orbiter are mounted on the sides of the large LO_2/LH_2 tank which the shuttle carries into orbit. They are designed to jettison at an altitude of about 25 miles for recovery and re-use.

A large part of the preliminary work now being undertaken by North American Rockwell concerns the mating of these units and the problem of achieving their recovery after burnout and separation.

Companies expected to tender for the development contract include Aerojet, Thiokol, Lockheed Propulsion and United Technology Center.

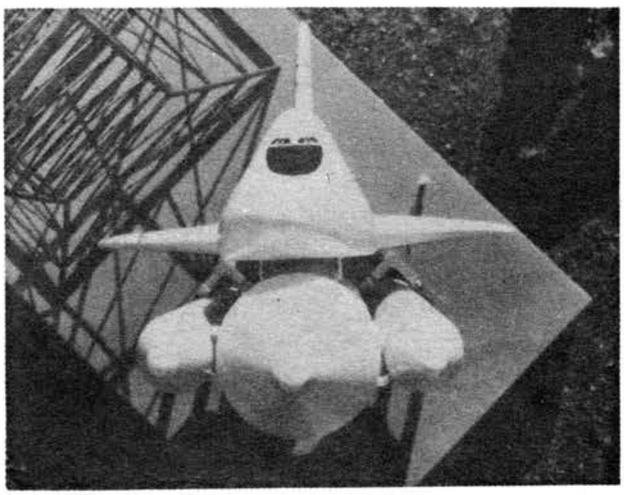
At present no manned spacecraft has been launched by solid rockets and UTC must have a clear advantage because of the wide experience they have gained with the 120 in. solid used on Titan 3C/D. More than 40 of these large boosters have been launched in pairs as booster stages of these major launch vehicles and they have all worked perfectly.

The units which UTC recommend are 3 ft. wider than Titan 3 boosters, have 3 segments plus end closures making an averall length of 184.9 ft. Each 1,415,000 lb. booster will have a 4,130,000 lbf. initial thrust, reduced by a shaped propellant grain to 2,600,000 lbf. after 40 sec.

It has yet to be decided if thrust vector control (TVC) will be neccessary on the boosters as the gimbal-mounted shuttle main engines may suffice for stability and control in the mated configuration. If, as seems likely, TVC *is* necessary UTC favour a gimballed nozzle system called 'Techroll' which they have developed under an Air Force Rocket Propulsion Laboratory contract.

The 'Techroll' nozzle for solid rockets employs a fluid bearing which gives the important advantage of requiring very small amounts of torque for nozzle rotation and reducing the size of an hydraulic actuation system. Moreover, studies have shown that a 'Techroll' TVC system on Titan 3 boosters would cost $200,000 to $300,000 less than the liquid injection TVC system currently in use.

We asked UTC to supply a technical note on the new movable nozzle development which we reproduce below.



The 'Techroll' Seal

The 'Techroll' seal is a constant volume, fluid filled bearing configured with a pair of rolling convolutes that permits omniaxis deflection capability of a rocket nozzle. The fluid filled bearing is pressurized by the nozzle ejection load and serves the dual purpose of moveable nozzle bearing and nozzle seal. The 'Techroll' seal is fabricated of a fabric reinforced elastomeric composite and does not require complex manufacturing processes or tight tolerances.

This simple new approach to moveable nozzle bearings has extremely low actuation torque, requires packaging volume equal to or less than other available techniques and offers the potential of significant savings in production cost. A range of potential systems applications include air-launched missiles, strategic missiles and space boosters.

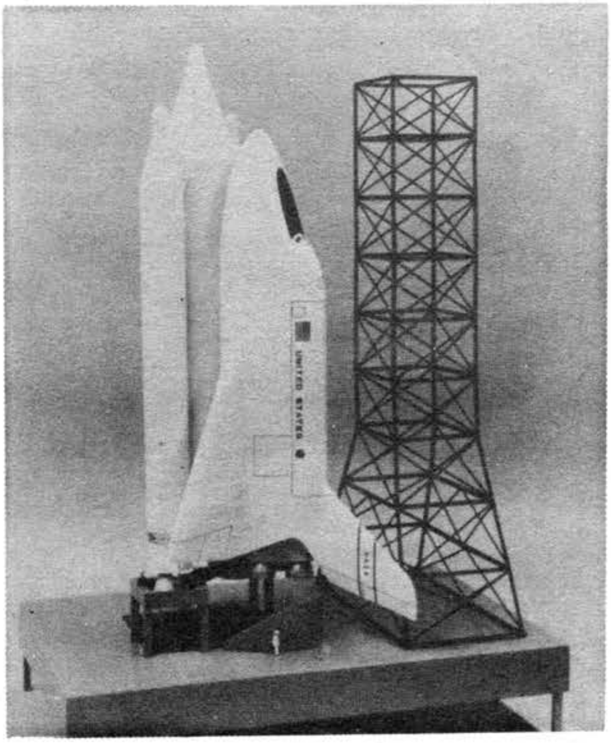
Requirement

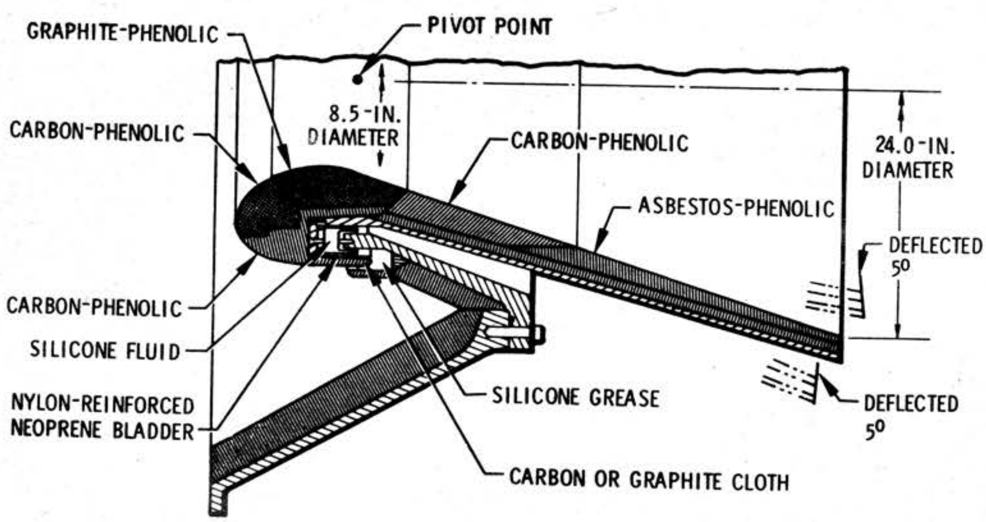
A primary requirement for a moveable nozzle TVC system is a bearing that resists nozzle ejection forces, permits the exhaust nozzle to be deflected with reasonably sized actuator systems, and has a seal which prevents leakage of exhaust gases. The 'Techroll' seal offers a unique approach to the bearing design which fulfills these necessary characteristics.

Preliminary testing of the concept at United Technology

[Text continued on page 17.

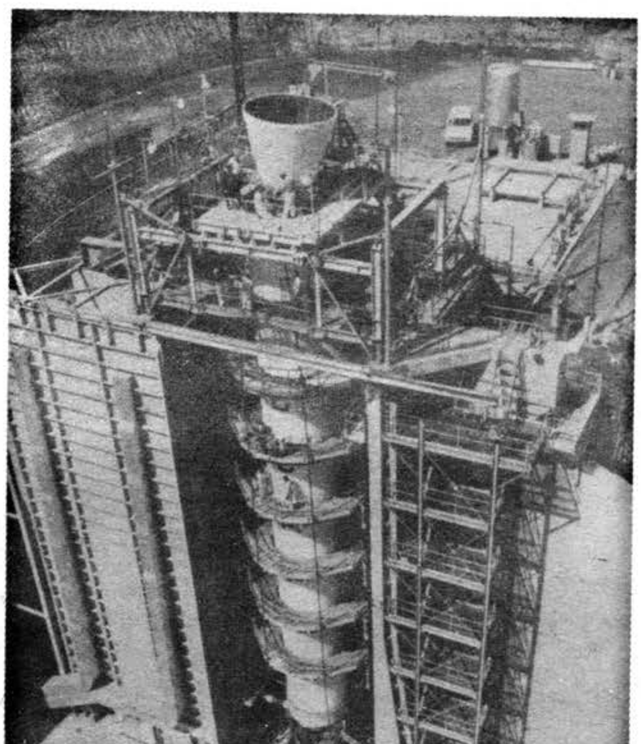
Space shuttle models by United Technology Center show the two solid boosters mounted on the sides of the large disposable LH_2/LO_2 tank of the fly-back orbiter.

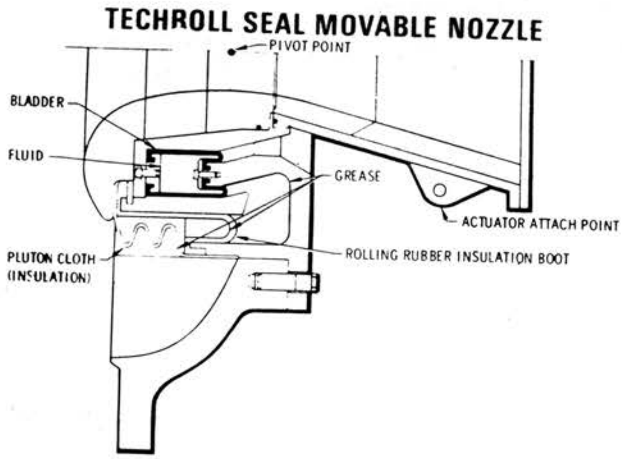




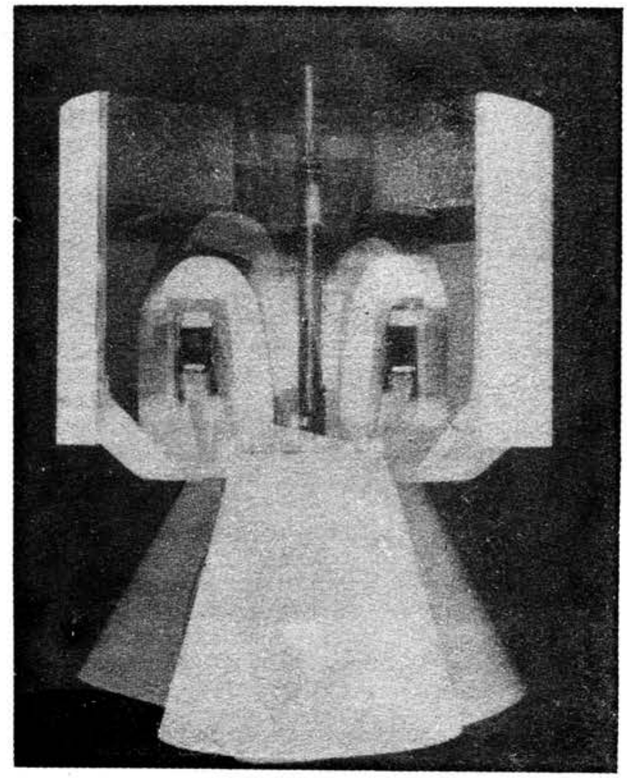
Left, sectional drawing of UTC 'Techroll' seal moveable nozzle assembly which has been proposed for the 156-in. solid boosters of the space shuttle.
Bottom left, engineers are dwarfed by this 7-segment 120 in diameter solid rocket motor being prepared for testing in 1970 at United Technology Center high in the mountains above the town of Coyote in Northern California.
Bottom right, entrenched over a mile away, observers watch the huge rocket motor being put through its paces. Weighing 350 US tons, it stands 112 ft. tall and burns 600,000 lb. of propellents, a synthetic rubber containing aluminium additives as fuel and ammonium perchlorate as oxidizer. Thrust is 1.4 million 1bf. The solid rocket motors planned for use with the NASA space shuttle will be 3 ft. larger in diameter.

United Technology Center





Cutaway model of the 'Techroll' seal movable nozzle.



Continued from page 15]

Center under actual solid rocket firing conditions has resulted in development and study contracts with the Air Force, Army and Navy.

Concept

The 'Technroll' seal is a fluid-filled, constant-volume bearing which is located between the nozzle and the motor case. The seal has an annular geometry with 2 rolling convolutes, as shown above. Easy pivoting of the nozzle occurs by the simple process of allowing fluid in the bearing to displace to the opposite side as the nozzle moves. Nozzle ejection is prevented by containment of the incompressible fluid of the bearing in the fixed volume of a fabric-reinforced seal.

The bearing pressure develops as a reaction to the nozzle blowoff loads during motor operation. During storage of a typical motor, the seal is essentially unpressurized (1 to 2 psi) for assurance of long storability.

The seal is supported by structure in all areas except in the region of convolute roll. The small convolute diameter allows low tensile forces readily obtainable with a single layer of rubber coated reinforcement cloth. These forces, characteristically on the order of 500-lb. per lineal inch, are well within the capabilities of nylon-, rayon-, or dacron-reinforced materials. A rubber coating material is used as a filler to prevent leakage through the weave in the reinforcing cloth. Many elastomers with shear strength substantially greater than the required operating loads are available for this purpose.

The nozzle can be actuated by a variety of conventional or advanced techniques. In addition to hydraulic or electro-mechanical actuators, servo-nozzle control using liquid or warm gas injection could be attractive.

Thermal protection of the 'Techroll' seal is accomplished conventionally using grease retained by a graphite or carbon cloth as is done on other flexible seal moveable nozzle systems. This is one of several methods available.

Low-density fluids utilized in the 'Techroll' seal are selected for long-term compatibility with the seal rubber coating. Silicone hydraulic oil has been successfully used and has 10-years compatibility with many seal coatings of interest. In practice, the viscosity of the fluid used can be selected to achieve whatever system damping is required. The potential for fluid loss is minimal since there are no sliding or pressure-actuated seals and since driving pressure during storage is essentially zero.

OBJECTS ON THE MOON

Readers Questions

Q. What are the positions on the lunar surface, of the following probes.

1. Lunar Orbiter 4, USA.
2. The S1VB stage from Apollo 14.

P.N.A.

A. Lunar Orbiter 4 (1967-41A) lunar impact site is not known at the present time; this spacecraft decayed naturally from lunar orbit and at the time of impact was not transmitting.

Apollo 14's Saturn S-IVB stage, Saturn AS-509 (1971-08B) impacted the Moon at astronautical selenocentric latitude 1°36' South, longitude 33°15' West.

SPACE REPORT

A regular monthly review of Space Events and Technical Trends

TELESCOPES IN ORBIT

The heaviest and most complex spacecraft yet to be developed by the United States for the sole purpose of observing stars and other celestial objects was launched from Cape Kennedy on 20 August. The 4,900 lb. (2,223 kg) Orbiting Astronomical Observatory OAO-3, which is orbiting some 460 miles above the Earth, has a 32-in. reflecting telescope developed by Princeton University to study ultra-violet emissions. A battery of 3 small telescopes provided by University College, London, observes X-ray emissions.

The robot space observatory, called Copernicus after the famous Polish astronomer, transmits results to ground stations on command. From the data received astronomers hope to find clues to the composition, density and physical state of matter in remote parts of the Galaxy.

The craft is so well controlled that it can be pointed and held steady on an object the size of a football about 400 miles (644 km) away.

The Observatory carries the largest optical telecope yet operated in space. It is stabilised with very great precision so that long-term exposures can be made on distant, very faint sources, and it can be swung from target to target under ground control. Data are stored in a computer-type memorv over several orbits, and are read-out from time to time via a few selected ground stations to be relayed directly to the operations control centre at the Goddard Space Flight Center near Washington, D.C.

University College London's Mullard Space Science Laboratory at Holmbury St. Mary, Dorking, which received SRC support totalling over £230,000 for space research during the past year, is making observations of cosmic X-ray sources using 3 reflecting telescopes, installed in the spacecraft. They are being pointed at known X-ray sources – so far 120 have been catalogued, about two-thirds of which are probably within our Galaxy – so that their positions can be established with greater accuracy than at present, and so that their spectral content can be measured in an investigation into the physical processes responsible for the emission of X-radiation. The 3 telescopes operate in the X-ray wavelength bands 0.30 - 0.90; 0.60 - 1.80, and 2.00 - 7.00 nanometres. The first 2 are provided with aperture stops; these can be adjusted on command from the ground so that the fields of view can be narrowed down once an X-ray object has been located. The X-ray telescopes, although quite separate instruments from the large 36 in. optical telescope, are mounted so that they move with it. This means that when the main optical observatory is in operation the X-ray telescopes can only observe the optical source under study, which may or may not emit X-rays. At other times the main telescope will cease normal operations, and with the spacecraft swung round to an X-ray source, the MSSL telescopes will make measurements as part of a separate, planned programme of observations.

There is no direct link between the large optical telescope and the three X-ray telescopes. Their observing programmes will proceed quite independently at first, but it can be expected that in time each will provide information relevant to the other's observations.

Data from the X-ray telescopes are being relayed by cable each day from the Goddard Space Flight Center to a computer at the MSSL so that the operation of the telescopes can be monitored daily, allowing decisions to be taken promptly about changes to the observing programme that may then become necessary, and data analysis commenced within hours of the measurements being made.

Guest observers have been invited to participate in the choice of sources to be studied and in the subsequent analysis, their proposals being co-ordinated by an Observing Panel. Scientists from the University of Leicester space science group, who were associated with the early stages of the work, are also participating.

Studies with instrumented sounding rockets and with earlier satellites, particularly by Explorer 42, better known as 'Uhuru', launched in December 1970, have shown that X-rays in amounts much larger than are generated by the Sun are propagated through the Universe from distant sources. Some of these sources, of which more than 200 have been identified, are apparently beyond detection by any means other than X-ray emissions.

By studying these sources with the satellite, scientists hope to gain a better understanding of energy production processes in the Universe which could eventually lead to new ways of generating power on Earth. Similarly, ultraviolet observations by the big telescope are expected to furnish information from which scientists can gain a better understanding about the development, present status and possible destiny of the Universe.

Information obtained from the spacecraft will be shared by researchers throughout the world and will publish in internationally available professional journals as has been the custom in the OAO and other U.S. space programmes.

OAO-3 is the last of a series of four U.S. astronomy satellites. The first, launched on 8 April 1966, failed after only 3 days in orbit because of a malfunction in its power system, The engineering experience gained, however, demonstrated that the concept of such astronomical investigation from space from scattering and absorption by the atmosphere, was feasible and led to improvements in future spacecraft. OAO-2, launched on 7 December 1968, has operated continuously since then, far beyond its expected lifetime. It carries ultraviolet viewing instruments designed by the University of Wisconsin, and by the astrophysical observatory of the Smithsonian Institution in Cambridge, Massachusetts.

In more than 10,000 observations of 1,500 celestial objects, OAO-2 opened to astronomers for the first time a formerly nearly closed window for sustained viewing of the Universe.

Through these ultraviolet observations, astronomers gained new insights into stars, galaxies, the Solar System, and the Earth's upper atmosphere, made some major observations of comets and, in May 1972, of a supernova, the momentary outburst of a star to a brightness millions of times greater than the Sun.

The third orbiting observatory, OAO-B, was launched on 30 November 1970, but failed to achieve orbit when a protective shroud could not be jettisoned, and the craft fell back to Earth.

The newest and last of the series, OAO-3, was launched by an Atlas-Centaur rocket into a circular orbit at an altitude of 460 miles. After the craft had been stabilized in orbit, a 12-day check of its systems was carried out by radio command from Earth. The craft then began its scientific observations.

Up to 1,024 ground commands can be stored in OAO-3's on-board computer, allowing fully automatic operation between the craft's daily Earth contracts when flying within radio range of the ground control and communications station at Rosman, North Carolina.

Housed in the centre of the 10 ft. long spacecraft is the 32-in. diameter reflecting main telescope. To reduce weight, the telescope's mirror was manufactured of thin, fused silica ribs. The mirror weighs 105 lb. compared to 360 lb. for a conventional glass mirror of similar size and quality. Ultraviolet light from a star being observed is collected by this mirror, which reflects it to a 3.9-in. second mirror from where the light is directed into a spectrometer, an instrument that analyzes the light optically and electronically. The spectrometer converts its findings about the light's intensity and wave length to a series of numbers which are telemetred to Earth. With the help of computers, scientists analyze this information and reconstruct the observations.

FUTURE OF PHYSICS

Physicists, those scientists who deal with non-living nature – matter and energy – recently looked into their mirror and were delighted with what they saw, writes Walter Froehlich. The physicists believe that their science stands at the threshold of fundamental discoveries which could profoundly affect Man's concept of the Universe and almost certainly significantly influence the lives of many millions of the Earth's inhabitants.

More than 200 US physicists participated in a 2-year self-examination that covered 69 specialist areas of their subject. Twenty-one senior physicists, including some of the most distinguished personalities from these specialities in government, industry and the academic community, summarized the study in one of the most comprehensive reports ever compiled on the status and the directions of research in a specific scientific field.

The 1,065-page report, accompanied by several smaller volumes of supporting documents, was published in mid-1972 by the US Academy of Sciences.

Entitled, *Physics in Perspective,* it assesses major trends and research opportunities, and envisions large returns in knowledge and practical benefits for mankind if the opportunities are properly exploited. New approaches, almost beyond imagination until a decade ago, might open in certain areas of medicine, electric power generation, astronomy, and materials technology.

One such approach is the possibility of assembling atoms into molecules to construct made-to-order raw material for drugs, fabrics, buildings and other uses with nearly ideal characteristics for each purpose. Such tailor-made materials are coming within the realm of possibility through advances in several areas of physics, including computer technology. With computers, the scientists could calculate in advance what any particular combination of atomic structures might accomplish.

Equally promising is research in 'Superconductivity', in which electricity can be transmitted with no loss of energy. Alloys used as conductors become superconducting only when cooled to within a few degrees of 'absolute zero' – about -459°F; -273°C. This requirement makes the technique impracticable for long-range transmission, but researchers are on the trail of suitable alloys which become superconducting at far higher temperatures.

Also for power generating, physicists theorize that through deliberate collisions of heavy elements they might be able to create durable 'superheavy elements' which could be used in convenient, portable, atomic power sources.

These 'superheavies' would presumably emit 3 times as much radiation as do present nuclear fuels and this might reduce 100-fold the 'critical mass' – the minimum quantity required to sustain a chain reaction in atomic fission. Such long-lived powerful 'vest-pocket' electric generators would allow development of a large series of new products. Some such heavy elements have been produced experimentally, but they 'decayed' within a fraction of a second to lighter elements.

Advances in acoustics, also a branch of physics, already permit construction of sound detectors so sensitive that such instruments in New York could 'hear' the launch of an Apollo craft at Cape Kennedy, Florida, 1,000 miles (1,600 km) away.

These and other developments in accoustics promise new kinds of artificial aids to simulate hearing and speech for the deaf and speechless. And in still other arenas of accoustics sound waves are being used experimentally to speed the healing of wounds in what could become a new medical technique.

Computers in cars and kitchens may become possible through new techniques of miniaturization, which is already permitting the cramming into a space of 0.06 cubic inches of 10,000 or more transistors, replacing in function the once bulky, delicate vacuum tubes. As mechanical and electric devices have extended the power of man's muscles, so these small electronic computers would expand the power of man's mind in common, everyday situations.

Antenna systems are now feasible that can catch spontaneous transmissions from very distant sources in the Universe, and the physics report outlines a 'very large radio array' of such antennae to gain a better understanding of the Universe's structure and, perhaps, discover messages from living beings near another star.

An extremely complex area of research in which activity should be increased, according to the report, is 'turbulence research', dealing with the flow of fluids and gases. It encompasses studies on the global circulation of winds to understand and predict weather, the movement of ocean currents for better transportation and fishing, the flow of blood through the heart and other parts of the human body, and phenomena encountered in supersonic flight.

Most fascinating of all, and endowed with the most stirring implications for philosophy and man's way of life, is physics research into the fundamental building blocks of the atom – the essence of the makeup of all matter in the Universe from the tiniest speck of dust or living creature to immense galaxies.

These basic building blcks are now believed to be 3 different forms of an elusive, so far still unseen bit of matter called the 'parton' or 'Quark'. All atoms and components of atoms – and all material objects in the Universe – presumably are made of these partons or quarks. The consequences of such a discovery are unforeseeable, but physicists believe it could lead to still unimaginable ways of producing cheap, abundant electricity and to new ways of using matter.

Research of this kind is entering a new dimension with

the placing into peak operation in mid-1972 of the US National Accelerator Laboratory at Batavia, Illinois, the world's most powerful 'proton accelerator'. It is expanding and supplementing research at the Stanford Linear Accelerator, Stanford, California, the world's most powerful electromagnetic probe, and several other large atomic research facilities in the US and elsewhere.

'Science is knowing', says the report, and 'knowledge thus won is about as permanent an asset as mankind can acquire... The full value of scientific discovery is concealed in its future.......to understand how things work is to see how...... better to accommodate Nature to Man and Man to Nature'.

SOLAR STORM DEFINED

Observations by Pioneer spacecraft during a series of enormous explosions on the Sun last August differed from scientists' expectations and provided new data on the solar atmosphere which is expected to lead to a better understanding of the Sun and similar stars. A first look at measurements made by Pioneers 9 and 10, some 213 million km apart but located along a direct line to the Sun, shows that ionized gases travelled more slowly and increased in temperature as they moved further from the Sun.

Participating scientists called the data, 'absolutely unique'. The intensity of the solar wind was an unexpected bonus to experimenters, who had planned to use the Pioneer line-up to measure solar gases in a 'quiet' state.

Pioneer 9, orbiting the Sun inside Earth's orbit, observed record solar wind speeds of 3.6 million km per hour while counters set to measure faster moving high energy particles (solar cosmic rays) were overwhelmed. During the storm the spacecraft counted particles at levels 4,000 times higher than usual, also a record.

By the time solar winds reached Pioneer 10, en-route to Jupiter and 328 million km from the Sun, they had slowed to half the speed measured at Pioneer 9. Meanwhile, temperatures had risen to 2,000,000°K., far above the usual 100,000°K.

The storm, located in solar region 331, produced three major explosions on 2 August and a fourth on 7 August. During a one-hour period on 7 August, the storm produced enough energy to meet the United States' demand for electrical power for 100 years at present rates of consumpion.

The intense solar activity warped Earth's magnetic field, causing power and communications blackouts in Canada, Sweden, Alaska, and the northern United States.

PIONEER 7 RE-LOCATED

Flight Directors for the Pioneer 7 spacecraft set a long distance record for finding and reviving a spacecraft that had turned itself off. The probe was on the other side of the Sun, 312 million km from the Earth, when its radio fell silent early last August.

Controllers reacquired Pioneer 7 'in the blind'. Although they could estimate the spacecraft's position, they did not know its exact location nor the precise frequency of its radio receiver. Pioneer 7 was so far away that round trip time for radio communication to the spacecraft and back to Earth was 35 minutes. In addition, controllers had to solve a puzzle: Which combination of a variety of possible malfunctions had caused the spacecraft radio to stop transmitting?

Pioneer 7 had operated effectively in solar orbit since 1966. Last September it was directly opposite Earth, outside Earth's orbit, at its farthest point away from the Sun.

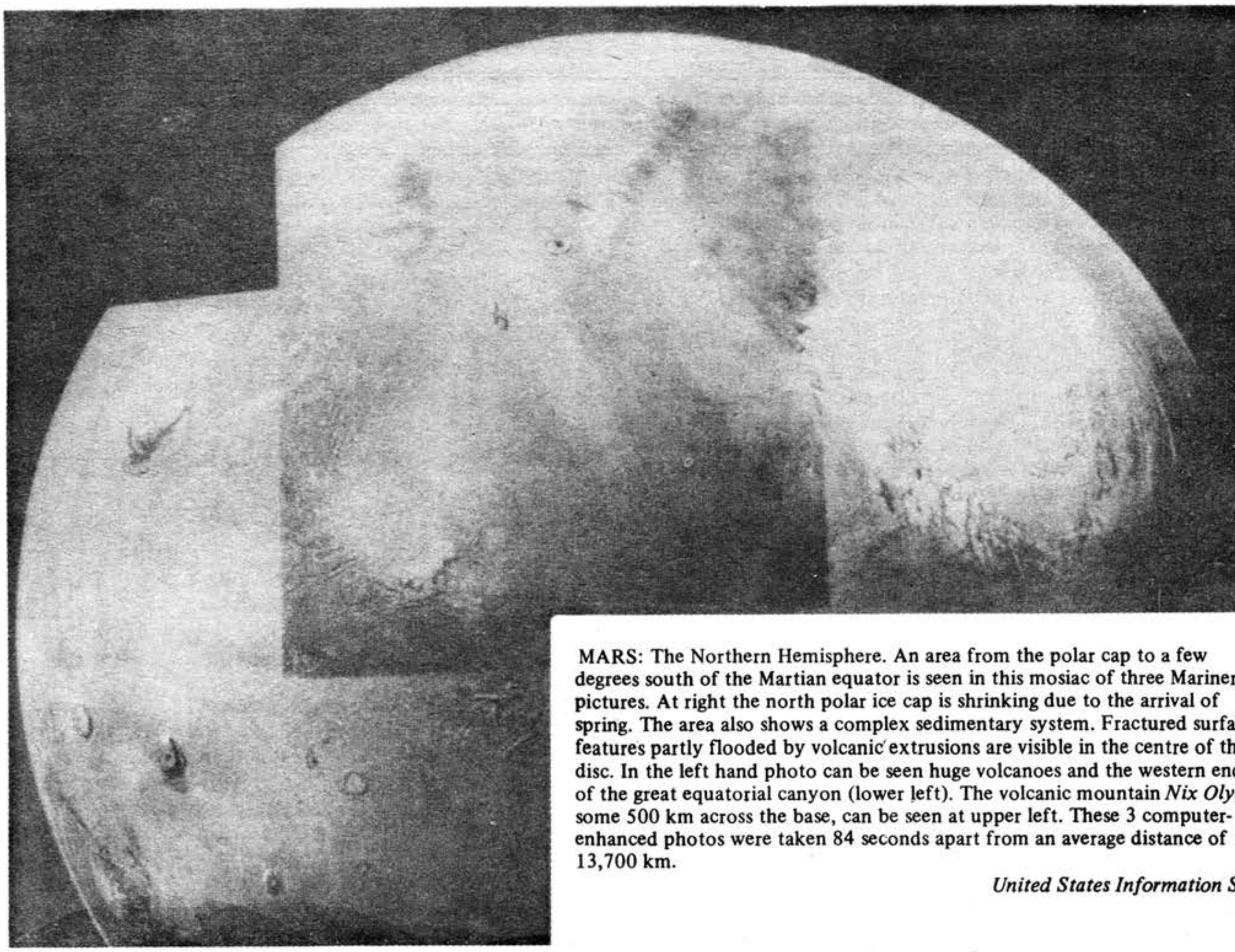
Norm Martin, Pioneer Flight Operations Director, at NASA's Ames Research Center, Mountain View, California, explained that 'because tracking time on the country's most powerful deep space antenna, the 64 metre dish at Goldstone, California, is needed for a number of spacecraft we don't track Pioneer 7 every day. Some time between 25 July and 6 August, Pioneer 7 stopped sending radio signals that could be heard by the Goldstone antenna. We theorized that at its farthest distance from the Sun electrical power output from the spacecraft's solar cells had fallen below the level required to operate the spacecraft and its scientific instruments. When power output falls below demands for power, the spacecraft automatically turns off the instruments and the power tube for the radio transmitter, which sends data to Earth. If, as we thought, this had happened when solar radiation was weakest,, we expected that turn-on of the radio transmitter power tube would be possible if the power requirements were reduced by leaving the instruments temporarily off. We determined where Pioneer 7 should be from past tracking data. We also calculated the frequency for the spacecraft radio receiver. If we were right, frequency would be different from normal because with the high-power transmitter off, the receiver would have cooled down about 50°, changeing its frequency. All these estimates proved out, after we sent the turn-on command from Goldstone – 35 minutes, and 388 million round-trip communication miles, later – back from the other side of the Sun came a solid signal from Pioneer 7 with data on its condition. Needless to say, we were pleased!'

JOINT PLANETARY EXPLORATION

The Academy of Sciences of the USSR and NASA have approved the recommendations of a joint working session of scientists on problems and objectives in the exploration of the planets. The participants agreed that among the scientific problems and objectives of the study of Mars are the need to determine the physical and chemical properties of the surface, to search for evidence of biological activity, to determine the precise composition of the atmosphere and to ascertain the role of water in the evolution of the planet. With regard to Venus, the group agreed that study should be directed towards understanding why and how Venus became so much hotter than the Earth (470°C. compared to 15°C. on Earth). This will involve determining accurately its atmospheric composition, the structure of the clouds, the depth of penetration of sunlight in its atmosphere and the characteristics of its surface.

The session also agreed that the study of the outer planets should place emphasis on the exploration of Jupiter and Saturn and their environments.

The parties exchanged views on the scientific problems of landing spacecraft on Mars and agreed that it would be useful to hold a subsequent meeting to jointly define promising Mars landing sites. They also agreed that a small group of US and Soviet scientists should meet to consider the scientific



MARS: The Northern Hemisphere. An area from the polar cap to a few degrees south of the Martian equator is seen in this mosiac of three Mariner 9 pictures. At right the north polar ice cap is shrinking due to the arrival of spring. The area also shows a complex sedimentary system. Fractured surface features partly flooded by volcanic extrusions are visible in the centre of the disc. In the left hand photo can be seen huge volcanoes and the western end of the great equatorial canyon (lower left). The volcanic mountain *Nix Olympica*, some 500 km across the base, can be seen at upper left. These 3 computer-enhanced photos were taken 84 seconds apart from an average distance of 13,700 km.

United States Information Service

problems involved in probing the atmosphere of Venus.

The working session was held in accordance with a recommendation of the Joint US/USSR Working Group on Near-Earth Space, the Moon and the Planets of 6 August 1971. Co-chairman of the working session were G.I.Petrov of the USSR Academy of Sciences and S.I.Rasool, Deputy Director, Planetary Programmes, Office of Space Science,NASA.

Soviet scientists declared an interest in landing an Automatic Micobiological Laboratory on Mars to analyse the soil and air for traces of living organisms in the newspaper 'Leninskoye Znamya' last March. The laboratory is intended to scoop up a sample of Martian soil to examine it for microorganisms such as bacteria, yeasts and fungal cultures. They said it had already been established that these might survive in a thin mainly carbon dioxide atmosphere and minimal water vapour. Martian air would be drawn in through a filter designed to trap microorganisms and analyse them.

The earliest opportunity for this experiment will be 1974. The launch window opens next July-August when Mars 4, 5 and (possibly) 6 are expected to be launched from the Tyuratam-Baikonur cosmodrome. Two NASA Viking spacecraft – which will also have biology experiments – must await the following launch window in August-September 1975. – Ed.

SPACE BIOLOGY REPORT

NASA and the USSR Academy of Sciences have approved recommendations developed at a second meeting of their Joint Working Group on Space Biology and Medicine. The meeting was held at NASA's Manned Spacecraft Center, Houston, Texas, on 12-18 May 1972, following the first meeting held in Moscow in October 1971.

The Joint Working Group continued its exchange of information, initiated in Moscow, of experiences in manned space flight. The U.S. presentations included the pre- and post-flight medical requirements and flight crew health stabilisation programme for Apollo 16, a discussion of the preliminary physiological results of that mission, and a glossary of space medicine terminology intended to aid in the mutual understanding of technical and scientific exchanges.

The USSR presentations detailed the medical findings of the Soyuz 11 and Salyut 1 mission, including the postflight autopsy results, the pre- and postflight clinical-physiological examination procedures of cosmonauts, and a special paper dealing with theoretical aspects of predicting crewmen physiological response during flight.

The data presented regarding the Soyuz/Salyut flight reveal no indication of deterioration of the physiological

status or performance efficiency of the crew during the entire course of the mission prior to the accident. The in-flight data were similar to those of previous Soyuz missions, and generally similar to in-flight Apollo data, and are consistent with both US and USSR findings that a general adaptive process occurs during weightless flight.

The medical information concerning the death of the cosmonauts presented by the Soviets confirms their previous announcement of a loss of cabin pressure. The death of the cosmonauts was the result of a rapid decompression of the landing capsule which occurred approximately half an hour before the spacecraft had returned to Earth. Specifically, the loss of pressure in the landing capsule to zero mm Hg. created conditions incompatible with sustaining human life. Thus, the causes of death of the cosmonauts were the occurrence of hypoxia and gaseous embolism (dysbarism).

A detailed review and evaluation of the data of the Soyuz/Salyut 24 day mission, the longest manned flight to date, reveals no indication of a need to modify current Skylab mission plans from a medical point of view.

An additional and significant development resulting from the meeting was the agreement that the Joint Working Group strive toward the development of common pre- and postflight medical examination procedures for flight crews. Attainment of this objective will permit direct comparison of US and USSR pre- and postflight data on selected body functional areas and thereby increase the information base of both parties regarding man's physiological responses to space flight.

As an initial step, four areas are being considered; namely, orthostatic tolerance (cardiovascular response), vestibular measurements, exercise-working capacity and biochemical examination of body fluids (blood and urine). Details regarding the procedures for these examinations will be exchanged through correspondence and current plans include in-depth discussions of these areas, during the next meeting in Moscow early in 1973.

Soviet Working Group members were Dr. O. G. Gazenko, Acting Chairman, Dr. L. I. Kakurin and Dr. P. V. Simonov. They were supported by four specialists in biology and medicine. U.S. Working Group members were Dr. Charles A. Berry, Chairman, Drs. E. J. McLaughlin and Harry Eagle, supported by experts from the Manned Spacecraft Center, Ames Research Center and NASA Headquarters. Dr. Edward Kass, National Academy of Sciences, was an invited participant.

SURFACE OF MARS

Scientists of the Institute of Radio Physics in Gorky suggested that the upper mantle of Mars is hard and porous. On Earth, such structures are called dendrites, and they are formed by the coking of granulated materials or as a result of the lengthy influence of proton or α particle radiation. The Martian substance contains 40-60% of silicon oxide of which one cubic centimetre weighs something like 1.6 grammes.

These beliefs are based on experiments which the Institute of Radio Physics have recently completed. The results deny the existence of an overlying dust mantle on Mars and suggest instead that there is no more than one millimetre of dust on the surface. Probably isolated dust regions comprising only an insignificant area of the planet's surface are the source of the dust storms on Mars, the scientists say.

Information has also been obtained on the nature of the white polar caps that change with the seasons. Measurements of temperature at the Martian poles, as well as photographs taken by automatic stations, provide grounds for maintaining that the polar caps consist of dry ice, hard frozen carbon dioxide.

MOON DATA EXCHANGED

The Academy of Sciences of the USSR and the NASA have approved the report of a joint meeting of experts on lunar cartography. The experts exchanged documents concerning lunar coordinate systems and map making. They agreed to recommend joint development of basic principles for compiling lunar maps, development of a joint programme for compiling a complete map of the Moon on a scale of 1 : 5,000,000 and the development of a common basic system of selendetic coordinates.

25 YEARS OF AEROSPACE TESTING

NASA's Flight Research Centre at Edwards, California, on the edge of Mojave Desert northeast of Los Angeles, celebrated its 25th Anniversary in September. The Centre is the testing ground for many of America's most advanced aircraft research programmes. It was created in 1947 to participate with the U.S. Air Force in flights of the X-1, the first plane to exceed the speed of sound in level flight.

These programmes have extended the boundaries of manned flight from subsonic speeds to more than 6·5 times the speed of sound.

A special ceremony to honour the Centre and the original 14 employees who participated with the Air Force in the testing of the X-1 at Muroc Dry Lake was held on 8 September in the presence of NASA Administrator Dr.James C.Fletcher.

During the 1950's, the Flight Centre carried on extensive research with the X-15. The experimental aircraft reached speeds of over 7,200 km/hr. and attained an altitude of nearly 110 km.

At the present time, researchers are testing wingless, lifting body, aircraft able to land without power. The Centre is also evaluating the 'supercritical wing' which will allow planes to fly at higher speeds without increasing fuel consumption, and a completely electronic flight control system expected to make future air travel much smoother. The control system employs components from the Apollo spacecraft.

The X-15, on loan from the Smithsonian Institution, and the Apollo 14 command module, were among the many exhibits on display at the open house. The Lunar Landing Research Vehicle, a free flying simulator used to test procedures for landing on the Moon, and a lunar rock from the first manned lunar landing mission, were also displayed.

SPACE TOILET

At last the National Aeronautics and Space Administration have been able to announce a big breakthrough in the

mod.cons. of space flight – the space commode. Under study for use in the space shuttle the commode can be used by both men and women passengers, both in space and during atmospheric flight, in the same manner as the toilets of jet airliners. Toe holds are provided on the floor as a necessary restraint under zero-g.

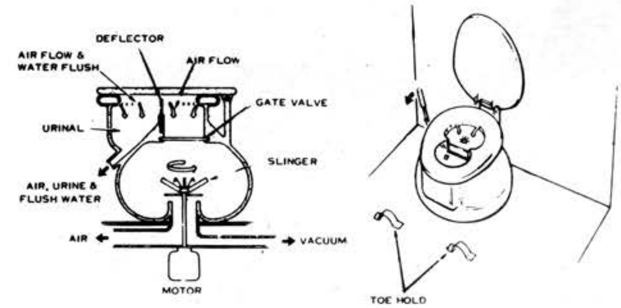
Separate receptacles are built into the seat for collection of liquid and solid body wastes. Under weightless conditions in orbit, high velocity airstreams will compensate for Earth's gravity to force waste matter into the respective chambers as it is excreted from the body. Airstreams also assist in the operation of mechanical water flush system for cleaning after each use.

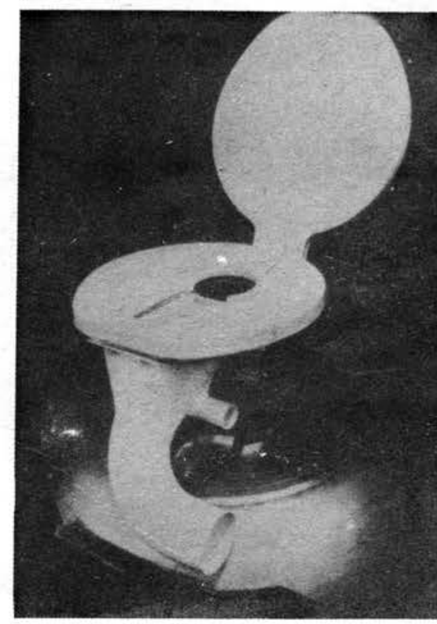
Waste matter is vacuum dried, stored and chemically treated to prevent odour and bacterial growth. The facility would be serviced when the shuttle returns to Earth in the same way as airline toilets are serviced at airports.

Commercial airliners are studying this type of vacuum drying and storage commode to reduce their present maintenance and operational costs.

A prototype of the space commode is being built by Hamilton Standard Division of United Aircraft, Windsor Locks, Connecticut, for testing and evaluation under a contract with the NASA Manned Spacecraft Center, Houston, Texas.

SPLIT-FLOW COMMODE CONCEPT





United States Information Service.

VENERA 8 RESULTS

When the 495 kg capsule released from Russia's Venera 8 spacecraft entered the atmosphere of Venus, its parachute descent lasted about an hour. At about 12.19 p.m. (Moscow time) on 22 July 1972, it made a soft-landing on the day side of the planet. Scientific instruments operated for 50 minutes after landing when data on the atmosphere, characteristics of the surface rocks and the condition of the capsule's equipment were transmitted to Earth.

Soviet scientists reported the following preliminary findings: Atmospheric pressure was about 90 kg/cm^2 and temperature 470°C, with 97% carbon dioxide and not more than 2% nitrogen as atmospheric constituents. Near the cloud layer there was less than 0.1% of oxygen and under 1% of water vapour. Measurements of the atmosphere made at altitudes of 40 km and 33 km indicated a small quantity of ammonia, possibly 0.01 to 0.1%.

Wind drift caused the capsule to deviate from the vertical descent path as it parachuted down. Measured at an altitude of more than 45 km the drift was about 50 metres/sec. but decreased to less than 2 metres/sec. At an altitude of less than 10-12 km, measurements indicated a zonal, latitudinal wind directed from the terminator (the boundary between the day and night sides of the planet) to the day side, i.e, in the same direction as the planet revolves.

Analysis of radio waves reflected from surface during the capsule's descent suggested that planet's surface layer is quite loose with a density under 1.5 grammes/cm^3. Preliminary data indicated that surface rock at the landing site contains 4% potassium, 0.0002% uranium and 0.00065% thorium. The proportion of radioactive elements resembles that of terrestrial graphite. On Earth such a ratio of elements is typical of rocks that have been subjected to secondary changes after melting out of the Earth's core.

Continued on page 30]

SATELLITE DIGEST — 54

A monthly listing of all known artificial satellites and spacecraft, compiled by Geoffrey Falworth. Information is based on that supplied by the Space Department of the Royal Aircraft Establishment, Farnborough, NASA, Satellite News and BIS sources. For information on the derivation of orbital parameters, abbreviations, etc., see July 1972 issue, page 262.

Continued from December issue, p. 463.

Name designation and catalogue number	Launch date, lifetime and descent date	Shape and weight (kg)	Size (m)	Perigee height (km)	Apogee height (km)	Orbital inclination (deg.)	Nodal period (min)	Launch centre, launch vehicle and payload/launch origin
Cosmos 498 1972-50A 6086	1972 Jul 5.40 5 months	Ellipsoid 400?	1.8 long? 1.2 dia?	267	490	70.95	92.12	Plesetsk Cosmos USSR/USSR
Cosmos 499 1972-51A 6090	1972 Jul 6.45 10.88 days (R) 1972 Jul 17.33	Sphere-cylinder 4000?	5 long? 2.44 dia	204	283	51.77	89.31	Tyuratam-Baikonur USSR/USSR
1972-51E 6113	1972 Jul 6.45 14.13 days 1972 Jul 20.58	Sphere?	2 dia?	171	269	51.76	88.84	Tyuratam-Baikonur USSR/USSR (1)
1972-52A 6094	1972 Jul 7.74	Cylinder-cone + boom 10250	15.25 long 3.55 dia	174 173	251 257	96.88 96.88	88.77 88.79	WTR SLC 4-East Titan 3D DoD/USAF (2)
1972-52C 6096	1972 Jul 7.74 3 years	Octagon? 60?	0.3 long? 0.9 dia?	497	504	96.15	94.66	WTR SLC 4-East Titan 3D DoD/USAF
Cosmos 500 1972-53A 6097	1972 Jul 10.68 7 years	Cylinder + paddles?	2 long? 1 dia?	505	549	74.07	95.18	Plesetsk USSR/USSR
Cosmos 501 1972-54A 6099	1972 Jul 12.25 15 months	Ellipsoid 400?	1.8 long? 1.2 dia?	221	2168	48.52	109.21	Kapustin Yar Cosmos USSR/USSR
Cosmos 502 1972-55A 6105	1972 Jul 13.61 11.7 days (R) 1972 Jul 25.3	Sphere-cylinder 4000?	5 long? 2.44 dia	204	262	65.40	89.16	Plesetsk USSR/USSR
1972-55E 6129	1972 Jul 13.61 13 days 1972 Jul 26	Sphere?	2 dia?	171	233	65.39	88.54	Plesetsk USSR/USSR (3)
Cosmos 503 1972-56A 6114	1972 Jul 19.58 12.70 days (R) 1972 Aug 1.28	Sphere-cylinder 4000?	5 long? 2.44 dia	202 169 170	288 314 308	65.43 65.41 65.41	89.40 89.33 89.27	Plesetsk USSR/USSR (4)
1972-56E 6134	1972 Jul 19.58 14.70 days 1972 Aug 3.28	Sphere?	2 dia?	163	295	65.46	89.08	Plesetsk USSR/USSR (5)
Cosmos 504 1972-57A 6117	1972 Jul 20.75 5000 years	Ellipsoid 40?	1.0 long? 0.8 dia?	1324	1498	74.02	114.03	Plesetsk USSR/USSR (6)
Cosmos 505 1972-57B 6118	1972 Jul 20.75 6000 years	Ellipsoid 40?	1.0 long? 0.8 dia?	1354	1498	74.03	114.37	Plesetsk USSR/USSR
Cosmos 506 1972-57C 6119	1972 Jul 20.75 7000 years	Ellipsoid 40?	1.0 long? 0.8 dia?	1384	1498	74.02	114.70	Plesetsk USSR/USSR
Cosmos 507 1972-57D 6120	1972 Jul 20.75 8000 years	Ellipsoid 40?	1.0 long? 0.8 dia?	1414	1498	74.02	115.03	Plesetsk USSR/USSR
Cosmos 508 1972-57E 6121	1972 Jul 20.75 9000 years	Ellipsoid 40?	1.0 long? 0.8 dia?	1446	1497	74.02	115.37	Plesetsk USSR/USSR

Name designation and catalogue number	Launch date, lifetime and descent date	Shape and weight (kg)	Size (m)	Perigee height (km)	Apogee height (km)	Orbital inclination (deg.)	Nodal period (min)	Launch centre, launch vehicle and payload/launch origin
Cosmos 509 1972-57F 6122	1972 Jul 20.75 10000 years	Ellipsoid 40?	1.0 long? 0.8 dia?	1475	1501	74.02	115.73	Plesetsk USSR/USSR
Cosmos 510 1972-57G 6123	1972 Jul 20.75 10000 years	Ellipsoid 40?	1.0 long? 0.8 dia?	1497	1512	74.02	116.10	Plesetsk USSR/USSR
Cosmos 511 1972-57H 6124	1972 Jul 20.75 10000 years	Ellipsoid 40?	1.0 long? 0.8 dia?	1496	1548	74.03	116.48	Plesetsk USSR/USSR
Erts 1 1972-58A 6126	1972 Jul 23.75 100 years	Conical frame + cylinder + 2 panels 891.32	3.05 long 3.35 dia	903	921	99.12	103.27	WTR SLC 2-West Delta NASA/NASA (7)
Cosmos 512 1972-59A 6130	1972 Jul 28.43 11.7 days (R) 1972 Aug 9.1	Sphere-cylinder 4000?	5 long? 2.44 dia	203	273	65.39	89.25	Plesetsk USSR/USSR

Supplementary Notes:

(1) Capsule ejected from 1972-51A at 1972 Jul 16.
(2) Orbital data at 1972 Jul 8.0 and Aug 1.0.
(3) Capsule ejected from 1972-55A at 1972 Jul 25.
(4) Orbital data at 1972 Jul 19.9, Jul 25.5 and Aug 1.0.
(5) Capsule ejected from 1972-56A at 1972 Jul 31.
(6) Fourth Soviet eight-payload satellite launch, 11th Cosmos multiple-payload mission and 14th Soviet multiple-satellite flight.
(7) ERTS A, first in a series of Earth Resources Technology Satellites, provides data on user-oriented Earth activities in agriculture, ecology, forestry, geography, geology, hydrology, land use management, meteorology, oceanography and pollution control. Main objectives of the spacecraft, consisting of a lower sensor and electronics assembly surmounted by a conical frame holding upper attitude control and solar panel subsystems, are to determine capability of spacecraft acquisition of Earth's global and natural and cultural resources and environment data, test and demonstrate use of Earth-orbiting sensor combinations in global Earth resources data acqusition, transmission, reception and utilisation procedures together with ancillary interpretive techniques for data application, determine how repetitive, synoptic, multispectral Earth observations by spacecraft instrumentation is of economic and social value to commercial, scientific and government interests, and provide data on operational procedures for operational Earth resources observation spacecraft. Similar to Nimbus 4 (1970-25A) Erts 1's 1000-watts power requirements are maintained by over 11000 negative-on-positive solar cells producing 512 watts at 35 volts mounted on two 2.43-metres long, 0.91-metre diameter solar panels deployed from the spacecraft's upper attitude control system assembly after orbital insertion and canted to a fixed solar-orientation angle after deployment to obtain maximum solar illumination during optimum spacecraft dayside equator transits. Eight individually-controlled onboard 6.80-kg battery modules, each containing 23 nickel cadmium cells each rated at 5.0 ampere hours having a 36 ampere hours nominal capacity and containing individual battery charge controllers sensing cell current, voltage and temperature and conditioning charges accordingly, provide backup, peak period and eclipse period power. Power control modules and payload regulator modules provide regulated power to each of Erts 1's sensors, each module containing two redundant regulators with automatic switchover to backup regulator if required within 50 millisecond of prime regulator malfunction. Spacecraft status regulator operates at -24 ±0.5 volts and is current-limited at 20 amp while payload regulator also operates at -24 ±0.5 volts and is current-limited at 26 amp. Constant spacecraft Earth-orientation and three-axis stabilisation to within ±0°.7 in pitch, yaw and roll axes is maintained by onboard frame-mounted three-axis attitude control system utilising horizon scanners for pitch and roll stabilisation control and gyrocompass system for yaw orientation while independent passive attitude measurement sensor operating over narrow, 2° range provides highly-accurate spacecraft pitch and roll alignment data to within 0°.07 for accurate Earth-acquired image location and orientation identification, and maintains spacecraft motion rates of less than 0°.4 per second. Onboard monopropellent hydrazine 0.05-kg thrust gas jets located in Erts 1's attitude control subsystem surmounting the spacecraft's conical frame structure provide orbit adjustment capability, nullify minor launch vehicle orbital injection errors and provide periodic spacecraft orbital manoeuvres to maintain nominal, Sun-synchronous, retrograde, near-polar Earth orbit permitting the spacecraft to transit and observe global subsatellite locations at about 0930 local time each day, orbital precession of nearly 1° per day causing a 25°.8 westward drift of each successive equatorial transit allowing slightly overlapping global surface coverage completion each 18 days. Erts 1's thermal control system, consisting of superinsulation blankets surrounding lower equipment areas, exposed areas adjacent to the spacecraft camera assembly locations to radiate excess heat to space, internal heaters to maintain onboard operating temperatures during minimum operating and eclipse periods, and bimetallic, thermally-activated spring louvre systems located around Erts 1's lower sensory equipment section, maintains overall structure and electronics equipment at about 20°C. Onboard telemetry system transmits science and engineering data to NASA's Space Tracking and Data Acquisition Network stations at Fairbanks, Goldstone, Goddard Space Flight Center at Greenbelt and to Canadian ground data acquisition station at Prince Albert, Saskatchewan through dual wideband antennae viewing Earth from Erts 1's base on command at 2229.5 MHz at 20 watts and 2265.5 MHz at 20 watts using FM modulators driving travelling wave tube amplifiers, while range rate and telemetry data are transmitted on command at 2287.5 MHz at 1 watt and Erts 1's tracking beacon transmits continuously at 137.860 MHz. Erts 1 is controlled by Goddard SFC's Earth Resources Technology Satellite Operations Center, while spacecraft data received by the three prime data reception stations is sent to NASA's Data Processing Facility at Goddard SFC and distributed as high-quality film images or digitised data on computer-readable magnetic

tape. Spacecraft VHF command receiver-demodulator receives and demodulates telemetry commands transmitted to Erts 1 by one of the three NASA ground stations, incoming signals being demodulated into discrete commands for spacecraft sensor and operational control. Consisting of two crystal-controlled, single-conversion, 154.20-MHz AM receivers, voltage regulators, telemetry circuits and subcarrier demodulators, prime and backup systems weigh 20 kg. Erts 1's Earth-oriented sensors include a co-aligned, three-camera, return beam vidicon subsystem viewing in sequence 185-km square, north-to-south areas of Earth's surface at blue-green 0.475- to 0.575-microns, red 0.580-to 0.680-microns, and near infrared 0.690- to 0.830-microns spectral regions respectively, combined 4000-lines per frame images from the three simultaneously-operated vidicon cameras being processed on Earth to consitute single, full-colour images containing radiometric and cartographic frame data. Each camera system includes a return beam vidicon using a magnetically-deflected, magnetically-focussed optical system having an f/2.8, 126-mm, high-resolution lens and 5.08-cm diameter face plate coupled to lens assembly-mounted spectral range-determining filters, lens assembly providing 15°.9-field of view across 2.54-cm square vidicon face plate's useable format diagonal, deposited reseau pattern on the vidicon face plate providing geometric reference required during Earth-based compilation of triple-images, shutter system, normally providing for one vidicon exposure per sequence but having programmable, five-exposure time capability to accommodate Earth-illumination variations, and thermo-electric cooling system controlling vidicon face plate's thermal environment. Camera shutter operation each 25 seconds producing overlapping Earth images allows photo-sensitive surfaces in each vidicon camera tube to record an image at each spectral wavelength which is subsequently scanned by an internal electron beam to produce video images which are either transmitted each 11 seconds to Earth stations in real-time or stored by onboard wideband video tape recorder for later transmission as Erts 1 becomes audible to ground stations. Each automatic camera operational mode sequence includes simultaneous vidicon face plate erasure, camera activation preparation, exposure and sequential vidicon three-image readout modes. Onboard data collection system utilises an Earth-oriented crossed dipole antenna acquiring telemetry at 401.5 MHz transmitted at regular timed intervals using a 5-watt, FM signal through a station-mounted, crossed-dipole antenna from Earth-based, remotely-located environmental information acquisition platforms measuring soil, water, air and other environmental parameters, converting ground-acquired data to Erts 1-compatible telemetry and transmitting telemetry including data from up to 8 different sensors in either analog or digital format to Erts 1 which records and re-transmit this data to ground stations. About 150 Earth-based data collection platforms transmit randomly every few minutes, Erts 1 transmitting platform and telemetry reception station mutual audibility allowing real time platform data relay operations at least each 12 hours. Erts 1 carries two simultaneously-operating identical 34.48-kg wideband video tape recorders each having a 15×10^6 bps digital bit rate, 3×10^{10} bits storage capability, 50.80-metres per second tape speed and dual return beam vidicon and multispectral scanner subsystem image record and reproducing capability incorporating transverse scan technique to receive image data outside direct data reception areas for later playback when Erts 1 is within audibility range of prime telemetry reception stations. Erts 1's recorder-associated electronics unit switches operating mode on command to receive either 3.2-MHz bandwidth return beam vidicon analog signals or 15×10^6 bits per second multispectral scanner system binary data stream. Erts 1's multispectral scanner subsystem scanning 185-km wide Earth strips using a mechanically-oscillating flat mirror 13 times each second in four spectral bands in the green 0.5- to 0.6-micron, red 0.6- to 0.7-micron and near infrared 0.7- to 0.8-micron and 0.8- to 1.1-micronwavelengths simultaneously acquires images for subsequent transmission to Earth through the spacecraft's onboard dual wideband antennae for combination into 185-km square frames corresponding to areas observed by onboard return-beam vidicon during operation, moving elliptical, 33-cm long, 23-cm diameter, silver-coated beryllium mirror oriented 45° to Earth's surface and using folded, 0.23-metre diameter Cassegrain telescope system and small secondary mirror oscillates 2°.9 about its nominal orientation scanning 11°.5 fields of view using internal electromagnetic torquing device and flexually-suspended rotating segment permitting oscillating mirror to rebound from bumpers reversing mirror movement during each oscillation cycle. Each of six scan lines imaged in each spectral band during each scan is focussed on a fibre optics array consisting of six separate fibres for each line within the four spectral bands arranged in a 6 x 4 matrix transmitting energy from each fibre optics light detector using either 18 photomultiplier tubes for visible spectral bands or silicon photodiode for infrared spectral band, while during scan retrace rotating shutter closes Earth-observation port and measures radiometric loads by reflecting light from onboard internal calibration source across fibre optic sensors, calibration light source accuracy being monitored by comparison with solar image acquired once each orbit by the fibre optics system. Onboard digital multiplexer electronics unit operates at 15×10^6 bits per second and encodes 24 analog scan data output channels and converts into high data rate digital bit stream for time-division and multiplexing, subsequent output being fed into spacecraft's modulator for real-time transmission or onboard data storage aboard Erts 1's wide-band video tape recorder for later transmission. Following nominal launch aboard Delta launch vehicle using a new inertial guidance system consisting of an Apollo lunar module-adapted inertial measurement unit using gyroscopes, accelerometers and associated electronics, providing vehicle attitude and acceleration data and 4000-word, 24-bit digital guidance computer, generating vehicle steering commands to each stage to correct trajectory deviations, new second stage engine adapted from operational Titan 3 transtage engine, new spring-separation system for positive separation of Delta's first and second stages, new launch vehicle S-band telemetry system for launch performance and engineering data transmissions during post-launch mission phases and to prevent conflict with other electronic communications signals, and first use of nine solid-propellent thrust-augmentation rocket motors, six of which ignited at launch and, following burnout, final three of which ignited at 6 km altitude, all nine empty rocket motors being jettisoned simultaneously 85 seconds after launch, Delta second stage separated from launch vehicle's first stage 3 minutes 40 seconds after launch and, about 4 seconds later, fired for 5 minutes 31 seconds to place the second stage and Erts 1 into an elliptical transfer orbit; 57 minutes into the mission over the Indian Ocean near Tananarive, Erts 1 second stage re-ignited for 11 second to circularise the spacecraft's Sun-synchronous orbit, following which Delta second stage's nitrogen gas jet system using eight fixed nozzles to provide roll control during powered flight and coast periods and pitch and yaw control following second stage cutoff, re-oriented the second stage/Erts 1 combination 80° from local vertical, while spring systems separated Erts 1 from the rocket vehicle 70 minutes 35 seconds after launch while the spacecraft's attitude control systems were subsequently activated to stabilise and orient Erts 1 in three axes. About 7 minutes after spacecraft separation Delta seond stage (1972-58B) was reignited to test second restart capability of modified stage. Erts 1 operated nominally following orbital insertion and good quality data was received from the spacecraft's multispectral scanner system and return beam vidicon system following activation during 1972 Jul 24 to verify satisfactory system operation. During 1972 Aug 3 a power surge, probably associated with one of Erts 1's onboard tape recorders was telemetered to Earth and the tape recorder was subsequently deactivated by ground command while pre-malfunction engineering telemetry was analysed to determine cause of the surge; three days later telemetry recorded a second power surge associated with the spacecraft's return beam vidicon camera system which was also deactivated while Erts 1's multispectral scanner system and second onboard tape recorder continue to operate nominally.

Decays:

OV1 18, 1969-25B, decayed 1972 Aug 27.99, lifetime 1258.67 days.
Cosmos 378, 1970-97A, decayed 1972 Aug 17.63, lifetime 638.46 days.
1971-91A decayed 1972 Jul 21, lifetime 273 days.
Cosmos 472, 1972-04A, decayed 1972 Aug 18.95, lifetime 206.48 days.
Centaur AC-27, 1972-12C, decayed 1972 Aug 18, lifetime 168 days.
Cosmos 481, 1972-20A, decayed 1972 Sep 2, lifetime 161 days.
Cosmos 485, 1972-28A, decayed 1972 Aug 30.23, lifetime 140.77 days

LIMITATIONS OF TERRESTRIAL LIFE

By Dr. P. Molton*

Introduction

With only 15 years intervening between this article and the first orbiting Earth satellite, Sputnik 1, the increase in knowledge in the field of Space Science has been tremendous. The number of man-made objects in space is now well into four figures, and space technology is in use in the most direct form with the advent of communications and meteorological satellites. Apart from the technological goal of increased efficiency and prosperity, ideological goals have been pursued. The major such goal, on which many billions of dollars and roubles have been spent, is the search for extraterrestrial life. This search is a source of hope for the human race, since there is no ulterior motive in it. There can be no military or political advantage in the discovery of a non-terrestrial living cell, yet the very intensity with which it is being pursued shows that it represents a basic need – to show that we are not alone in the Universe.

What is Life?

With man-made probes on the surface of the Moon and Mars, we are still not entirely clear as to what constitutes life. There has been a plethora of books and articles on the subject – and still there is disagreement. The eight functions of life as defined in the Biology textbooks are a useful starting point, but there is the question of how many exceptions can be tolerated without invalidating the definition. For instance, computers could be built which would generate their own power, be mobile, build other computers ('reproduce'), etc. Do we define them as living, if they satisfy the eight conditions of the textbooks? Viruses are non-mobile and can only reproduce in the presence of a more nearly living system. They are usually included among the realms of the living, despite their failure to satisfy the conditions. Any definition true for all cases of terrestrial life must be so hedged with qualifications that it would almost certainly exclude a true extraterrestrial organism as living, if one were found. We could specify the use of water as a cell constituent, and find that liquid ammonia was used in some systems in its place. The only final answer seems to be that a definition of life depends on the knowledge, experience and optimism of the one defining it.

The same sort of confusion pertains when we come to consider the range of conditions within our Solar System where life might be possible. Statements that 'life is impossible on Jupiter', for instance, lie side by side with statements of the opposite case. Many millions of words have been used in repeating facts about the conditions on the various planets in the Solar System, with one or the other conclusion tagged on the end. There seems to be little point in doing this. Our beliefs about extraterrestrial life are so coloured by our own experiences they they are often invalid. An example of this was given in a previous article [1], where the attitude of an alien when presented with the fact of photo-synthesis was illustrated. We will believe that which is similar to something in everyday life, and are sceptical of that which is not. For any student of Exobiology, the primary statement is that 'anything is possible'. He can go on from there to provide restrictions, if necessary. It is, after all, one of the main tenets of Science that we do not start with preconceived ideas.

In the final analysis, the only acceptable analysis is based on facts deduced in the laboratory or in the field – in this case, in space. Certain facts are available to us already, pertaining to the ability of our form of life to tolerate unusual conditions. Bacteria can survive prolonged exposure to vacuum, temperatures above 100°C., pressures above 1500 atmospheres, and pH in the range 0 - 14. The list could be prolonged, and yet it is only recently, as a result of laboratory investigation, that the great flexibility of terrestrial life has been realized. The work of Siegel, concerning the survival of cacti under water, and onion germination in ammonia, are other expamples [2-4].

Terrestrial life is only one of three major subdivisions of conceivable life, the other two being carbon-based but alien life forms, and exotic forms which may not be based on carbon, respectively. The degree to which these are believed to exist in the Universe is entirely a function of the breadth of our imaginations. We are certain of the existence of terrestrial life and need to use no imagination concerning it. The other two required considerable imagination and there is no evidence whatsoever for their existence.

The question of intelligence is a limiting factor cutting across all three classes, since we have no evidence that the existence of intelligence is limited to a specific chemistry. Just because we consider ourselves intelligent, and have a carbon-hydrogen-oxygen biochemistry, does not mean that the one entails the other. This would be arguing the case for a general law from a single example.

Beginning with the simplest approach to the problem of extraterrestrial life, that of the suitability of other planets in our Solar System for terrestrial organisms, there are three distinct questions. These are: 'Will it survive?', 'Will it grow?', and 'Would it have evolved here?' Survival experiments entail exposing organisms to alien conditions for a specified time, returning them to optimum growth conditions, and seeing if exposure has affected their ability to grow. Growth experiments require actual growth under the alien conditions for positive results. The third question is more difficult. On Earth, the conditions under which life evolved are not the same as those pertaining at the present day. It is believed that a methane/ammonia atmosphere was involved, gradually changing to our present nitrogen/oxygen mixture. While these changes are known in outline, details are unknown, and a definitive answer to the problem for another planet is beyond our present capability.

Experiments

Some experiments have been done under simulated planetary conditions to see if terrestrial organisms can survive there. Mercury, the Moon, Asteroids, satellites, and outer planets with the possible exception of Jupiter, are at present believed incapable of supporting terrestrial-type life. Survival, but not growth, of micro-organisms has been demonstrated for simulated Martian [5], Jovian [6], and Venerean [7] conditions, and in space [8]. Growth of algae under conditions similar to, but less stringent than, Venerean has shown [9]. The prospect for life on the outer planets has been summarised in a comprehensive recent paper [10], and there is a great deal of literature concerning life on other planets [11-12]. Of the places in the Solar System where growth may be possible, the planets Venus, Mars and Jupiter seem the most likely. The Moon is excluded on the basis of the Apollo findings. The poles of Venus may just be suitable for a modified terrestrial organism to grow. Likewise, the Martian equator

---

* *Exobiology Division, Ames Research Center, Moffett Field, Ca. 94035, U.S.A.*

and the possible aqueous Jovian cloud layer [6].

When the third boundary for the presence of life is applied, that of evolution, only if Mars and Venus previously had atmospheres different to those existing at the present day, namely methane and ammonia instead of the present-day carbon dioxide, could life have evolved. Jupiter is a different case, since the gravitational field of the planet retains all gases, including hydrogen, and we have no reason to suppose that its atmosphere has ever changed. Since this atmosphere contains methane and ammonia, we must conclude that evolution there is within the bounds of possibility. Evolution, that is, of life very similar to terrestrial life, taking the narrow assumption that this is the only form possible. However, the aqueous cloud layer of the planet is a very tenuous medium for life, and it may well be that some evolution conditions, such as an abundance of minerals for adsorption and membrane formation, never occurred there.

On the basis of this discussion, we conclude that the chances of finding life very similar to terrestrial life on another planet within our Solar System is slight. This is the result that common sense would have led us to expect. No two planets within the Solar System have identical conditions, so why should they harbour identical life forms? As for the prospect of finding terrestroid life on other planets not of our Solar System, the same argument applies: If conditions are identical to those on Earth, and were in the past, during the course of evolution, then the life may be expected to be identical in form.

Hence we are not likely to find creatures like ourselves in space. This is not such a great loss,perhaps.

If we assume that to conceive of terrestroid life on another planet does not require much imagination, then to conceive of a modified terrestroid life form does not require a great deal more imagination. Mere modification of that which we know exists is a deductive process, not an intuitive one. It follows that the least modification is the easiest to deduce, and this would apply on the planet most similar to the Earth. This is Mars.

Life on Mars?

Conditions on Mars, briefly, are an atmospheric pressure of about 7 millibars at ground level, composed mainly of carbon dioxide and nitrogen, with some carbon monoxide and oxygen derived from photo-dissociation, and a ground temperature at the equator in Summer of about 5°C. max. Solar radiation at ground level is rich in short wavelength ultraviolet. The surface is of limonite or basalt, with water in very short supply,and probably very little organic material that could serve as the basis for metabolism [14]. There may be a source of organic material arising from the radiolysis of carbon monoxide [15]. This would be mainly glycolic acid, formaldehyde, and similar materials.

These conditions are severe, but not necessarily lethal. Since terrestrial organisms can survive the freeze-thaw cycle of Martian day and night [16], the only modification needed to permit growth would be a more concentrated intracellular fluid than required on Earth. The UV radiation has been shown to be lethal to common terrestrial bacteria [5], but others are known which would be unaffected by it, being capable of self-repair. Otherwise, the organisms could attain safety by remaining below the surface. A few millimetres would be adequate to give protection. The only unknown factor is the low atmospheric pressure: Most organisms are killed by near-vacuum, but some have been shown to survive.

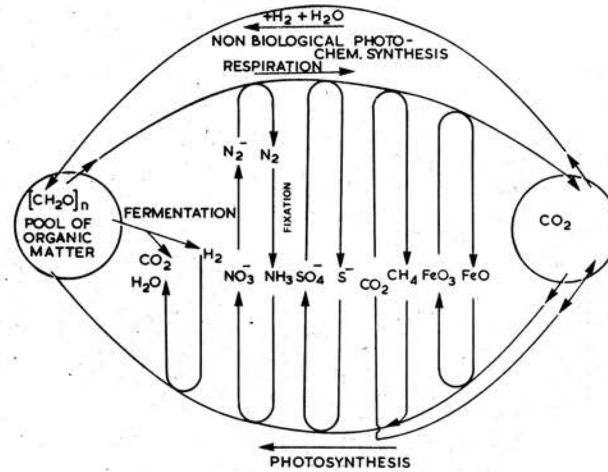


Fig. 1. Possible energy cycles on Mars [17].

That they would be able to grow is unproven, but a modification of the mechanism involved in active pumping of cell nutrients, so that gases and volatile materials could be preserved, would solve this problem.

A very plausible Martian system was suggested by Vishniac [17] (Fig. 1.), in which there would be oxidation of a pool of organic compounds to carbon dioxide, using the energy for the synthesis of complex cellular constituents. It has been shown that carbon monoxide can be converted to glycolic acid and formaldehyde by UV radiation similar to Martian sunlight, by an unknown mechanism [15]. Most of the carbon monoxide is oxidized to carbon dioxide, so the system is not very efficient. However, these compounds could be incorporated into cells by common terrestrial metabolic pathways. Energy for the conversion could come from a modified photosynthesis, utilizing the UV radiation rather than the longer wavelength red light used by plants on Earth. The same energy source could be used to supply other elements used in metabolism, as indicated in Fig. 1. In the absence of a sufficient supply of reduced organic material for energy production, some form of organolithotropic organism would predominate, converting, for instance, Fe^{2+} to Fe^{3+}.

Life on Venus?

Venus is the next in order of similarity to Earth in respect to probable Biochemistry. Conditions on its surface are still obscure, but include temperatures of up to 400°C. at the equator, dropping to a possible low of 160°C. at the poles [18]. The atmosphere is mainly of carbon dioxide at pressures of 60-80 atmospheres; small amounts of carbon monoxide and free oxygen are probable. Water may be present in abundance, despite failure to detect it by Mariner and Venera probes, since it would be trapped in the lower levels of the atmosphere. Under the prevailing conditions, it would be a liquid [19], heavily loaded with minerals dissolved from the rocks by the acidic carbonic acid. If we take the least adverse set of conditions – those at the poles, where salt seas may exist, with atmospheric pressures of below 50 atmospheres and temperatures of below 200°C. – some

form of modified terrestrial life may be possible. Experiments have been performed, as yet unconfirmed, [7], to show that common terrestrial bacteria can survive these conditions for up to a day. However, they do not *grow*. What modifications would be required to allow growth? High pressure in itself is no problem, since deep sea microbes exist on Earth which not only withstand but actually require pressures of up to 1800 atmospheres for their existence [20]. The absence of a carbon source other than carbon dioxide would mean that a photosynthetic cycle would be needed. High acidity and salt concentrations would have to be tolerated – and in fact both of these conditions have been shown to *aid* the survival of terrestrial bacteria at high temperatures. Some repair mechanism would be required against the destructive effect of high temperatures. This is the major requirement. Since terrestrial organisms are able to exercise direct active repair of radiation damage (e.g. *Micrococcus radiodurans*) [21], and this damage is no more than the destruction of cell components by energy, a similar system should serve for heat damage repair. Provided that conditions suitable for evolution once existed, there is no reason why Venus should not harbour life at the present time.

Life on Jupiter?

The only other place in our Solar System where we might expect to find a modified terrestrial life form growing is the planet Jupiter. This is first surprising, but the reasons behind this assumption have been explained in a previous article [1]. Briefly, despite the high pressures and low temperatures of Jupiter, there is believed to exist a region of water clouds at a temperature of about 20°C. and a pressure of 100 atmospheres. The atmosphere is mainly of hydrogen and helium, with small amounts of ammonia and methane. Survival of terrestrial organisms under these conditions for up to 1 day has been reported [6]. Growth of modified organisms is possible – they would need to spend their existence 'air-borne', away from the supercritical hydrogen 'sea' and the very cold upper layers of the atmosphere; minerals would be in short supply, and the only source of organic material for metabolism would be the steady rain of nitriles, amines, etc., from photolytic reactions in the upper atmosphere and from lightning discharges. There is no oxygen, so the metabolism would be strictly anaerobic. However, there is plenty of hydrogen, and this is a good reducing agent. Reduction of partially oxidised compounds back to methane and ammonia would yield plenty of energy for metabolism. The ecology of this system would be simple, consisting only of the process of organic synthesis and that of respiration (reduction with hydrogen). Photosynthesis could be ruled out, since the atmosphere supports several opaque cloud layers.

Other Planets

The other planets of our Solar System have conditions too widely different from terrestrial conditions to permit our form of life to exist there without so much modification that it would be unrecognizable. Pluto is too cold, Mercury too hot, the others somewhere in between. Although the range of conditions under which terrestrial life has been shown to survive has broadened in recent years, there has to be a limit to its capacity.

If we extend our view out of the Solar System, then of course there must be planets sufficiently similar to the Earth for similar types of life to have evolved. There is no reason why we should consider ourselves unique in this respect. In fact, the probability of life is high, since the assumption that planet formation is a natural and common event leads to the further assumption that planets will follow a common pattern with respect to their structure and composition. This can be seen even within the Solar System – the gas giants form a group, the Earth-type planets form an inner group. They are not intermingled, with Mercury after Saturn, or Jupiter nearer to the Sun than the Earth. Once we have assumed that planets are common, a whole series of such consequences follow. Intelligence may be an inevitable by-product of evolution!

Conclusions

In conclusion, then, life 'as we know it' is limited to the Earth, of all the planets in the Solar System – as a consequence of natural law and not by chance – and life similar to ours but modified to fit the prevailing conditions could exist on Venus, Mars and Jupiter. Of these, only in the case of Jupiter is there any evidence that life would have been able to evolve. The existence of intelligent life in all three cases seems unlikely. On Venus, an intelligent plant would be required. On Mars, the metabolic energy from carbon compounds to carbon dioxide would be too low (the high energy yield of Earth life arises from oxidation directly with elemental oxygen; anaerobic metabolism yeilds much less energy, and there is little or no free oxygen on Mars). On Jupiter, life would be restricted to the clouds, having therefore an upper limit to size – probably microscopic.

This result is only surprising to those that have given the matter little thought. We have considered only life similar to our own, and admitted the possibility of only minor variations. This is tantamount to looking for life in Earth's oceans – and specifying that it must breathe gaseous air. Special conditions such as possession of an aqualung are permitted, but our condition excludes gills. We would not be surprised at failure in the one case. Why should we be in the other?

The method of searching for life in the Universe most likely to be successful would be to start with no premises other than that of 'anything goes'. If it does not deny natural law, then it must be possible. The pessimistic conclusions reached in the present article are really the direct result of the assumptions with which we started. These assumptions are not the only ones, nor are they necessarily the correct ones. There is no law that states that we have to assume the worst possible case, as has been done here. Taking the opposite viewpoint, other conclusions are possible. Some possible life forms based on the assumption of optimistic parameters will be examined in a future article.

REFERENCES

1. P. Molton, 'Exobiology, Jupiter, and Life', *Spaceflight*, **14**, 220, (1972).
2. S. M. Siegel, *Spaceflight*, **12**, 128, (1970).
3. S. M. Siegel, *Spaceflight*, **12**, 256, (1970).
4. S. M. Siegel, *Spaceflight*, **13**, 183, (1971).
5. R. H. Green, D. M. Taylor, E. A. Gustan, S. J. Fraser and R. L. Olson, *Space Life Sci.*, **3**, 12, (1971).
6. P. Molton and C. Ponnamperuma, 'Survival of common terrestrial micro-organisms under simulated Jovian conditions', *Nature*, **238**, 217 (1972).
7. P. Molton, J. Williams and C. Ponnamperuma, unpublished results.

8. J. Hotchin, P. Lorenz and C. Hemenway, *Nature*, **206**, 442 (1965).
9. J. Seckbach and W. F. Libby, *Space Life Sci.*, **2**,121, (1970).
10. C. Sagan, *Space Sci. Revs.*, **11**, 827 (1971).
11. C. S. Pittendrigh, W. Vishniac and J.P.T. Pearman (eds.), *'Biology and the Exploration of Mars'*, Publ. 1296, National Acad. Sci., Washington, D.C.,1966.
12. E. A. Shneour and E. A. Ottensen, *'Extraterrestrial Life: An Anthology and Bibliography'*, Publ. 1296A, National Acad. Sci., Washington, D.C., 1966.
13. P. Anderson, *'Is There Life on Other Worlds?'*, Craver-Collier Press, 1963.
14. C. M. Michaux, *'Handbook of the Planet Mars'*, NASA SP-3030, 1967.
15. J. S. Hubbard, J. P. Hardy and N. H. Horowitz, 'Photocatalytic production of organic compounds from CO and H_2O in a simulated Martian atmosphere', *Proc. Nat. Acad. Sci.*, 1971, **68**, 574, (1971).
16. R. S. Young, P. Deal, J. Bell and J. Allen, *Nature*, **199**, 1078 (1963).
17. W. Vishniac, 'Exobiology: The Search for Extraterrestrial Life', ed. M. Freundlich and M. Wagner, AAS Science and Technol. Series, Vol. 19, p. 97 (1969).
18. L. R. Koenig, F. W. Murray, C. M. Michaux and H. A. Hyatt, *'Handbook of the Planet Venus'*, NASA SP-3029, 1967.
19. R. R. Stoecker and C. E. Folsome, *Space Life Sci.*, 2, 301, (1970).
20. C. E. ZoBell, *Recent Res. Fields Hydrosphere, Atmosphere, Nucl.* Geochem., 83 (1964).
21. C. J. Dean, P. Feldschreiber and J. T. Lett, *Nature*, **209**, 49, (1966).

Space Report/*Continued from page 23]*

U.K. – CANADIAN STUDY OF QUASARS

Canadian and British radio astronomers have begun a joint experiment to shed new light on the nature of the baffling cosmic objects known as quasars. The team, composed of scientists from the National Research Council of Canada, the University of Toronto and Queen's University on the one hand and the Radio and Space Research Station of the United Kingdom Science Research Council on the other, have combined the signals from quasars that were received simutaneously on radio telescopes in Canada and England, 3,270 miles apart. Such an arrangement, known as a radio interferometer, has an ability to distinguish detail which improves with separation between the telescopes and with decreasing radio wavelength.

Quasars, also known as quasi-stellar radio sources because of their very small star-like appearance, are believed to be the most distant objects in the Universe and are extraordinarily powerful emitters of radio waves. The radio emission is thought to be produced by high-energy electrons travelling in weak magnetic fields and to extend over a region which appears, as do distant stars, to be very small. So compact are the quasars, that interferometers capable of very fine discrimination of detail are needed for any meaningful measurements at all.

The new interferometer uses an unusually short wavelength of 2.8 cm. at both telecopes, a 150-ft. reflector at the Algonquin Radio Observatory, Ontario, Canada and an 85-ft. reflector at Chilbolton, England. The combined instrument can measure detail as small at 0.0004 sec. of arc – the equivalent of being able to stand in England and distinguish a marble held in Canada. Detail of this order has been found in several quasars.

The improvement in the interferometer comes about largely from the use of hydrogen maser atomic clocks, which allow the observations to be made at short wavelengths. Not only does this improve the discrimination of detail, but the detail itself is different at short wavelengths. Intriguing evidence from previous short wavelength observations of some quasars suggests that their size is rapidly changing. These observations can be interpreted in at least three ways: the quasars are expanding faster than the speed of light if they are at the distances inferred from the shift in wavelength of their spectral line; they are expanding at reasonable speeds and are much closer, or we are the victims of a form of optical illusion which depends upon special conditions in the quasar. Because of this puzzling variability in quasars the observations will be made at intervals of a few weeks for approximately a year.

For the experiment to work, observations from the two telescopes must be synchronized to within one ten millionth of a second and the tuning of the two receivers must be maintained identical to within one part in 1,000,000,000,000 (one trillion). The hydrogen maser clocks, which take a million years to gain or lose a second, make this high degree of accuracy possible. Quasar signals are recorded at each telescope with TV tape recorders and are finally combined after transporting both sets of tapes to the Astrophysics Branch of NRC's Radio and Electrical Engineering Division in Ottawa.

JAPAN'S 'DEMPA' SATELLITE

Following the launch of Japan's latest satellite, 'Dempa', into an unplanned orbit by an Mu-4S rocket on 19 August 1972, the National Space Development Agency announced that it had developed a fault in the encoder which had led Tokyo University to abandon a research programme involving five major on-board experiments. However, the 165 lb. Radio Exploration Satellite was still responding to ground commands and sends fragmentary data on plasma density in Earth's magnetic field and ionosphere.

SOVIET PLASMAJET

The mockup of a proposed Soviet satellite equipped with plasmajets has been put on display in Moscow. The eight-sided body has a flared base and is covered by solar cells. On top is a domed cylinder containing a small low-temperature plasma generator which feeds orientation nozzles.

WILLIAM HALE — A FORGOTTEN BRITISH ROCKET PIONEER*

By Frank H. Winter†

Introduction

No overall history of the development of the solid propellent rocket should fail to mention two names: Sir William Congreve [1] and William Hale. Yet while Congreve is well known and justifiably lauded, the other is obscure and has been neglected.

It was William Hale who invented the first successful spin-stabilized or rotary rocket in 1844, thereby eliminating the cumbersome guidesticks of the older Congreve rockets. Hale also developed the method of loading rockets by hydrostatic pressure. These achievements, though long forgotton, were the demarcation between the first crude, hand-made stick stabilized rockets of the Congreve era and the first machine-made, all metal stickless rockets of the height of the Industrial Revolution. For apart from dispensing with the old fashioned wooden guidesticks and improving accuracy and stability of rockets through spinning, Hale adapted new discoveries and inventions in metallurgy and machining to rockets and created his own revolution in the state of the art.

The Hale rocket, like the Congreve rocket before it, also eventually became absolete — primarily because of the great advance of other weapons — he nonetheless must be credited with passing on important technological legacies for our own age. In retrospect, perhaps his greatest contribution may be said to have been his lengthening the life of the old military rocket by 40 or 50 years and therefore keeping alive its associated technology and possibilities for further application.

In his own day Hale was highly regarded by military and engineering circles in every advanced nation and was known personally or by name to such sovereigns and statesmen as Queen Victoria and Prince Albert, Emperor Franz Josef of Austro-Hungary, Emperor Napoleon III of France, President Abraham Lincoln of America and Lajos Kossuth, the exiled leader of the short-lived Hungarian Republic (April-August 1849). It was during Hale's brief but stormy relationship with the latter that he received his greatest exposure from history's spotlight. This encounter marked the mid-point in Hale's remarkable career. His origin and earlier phases of this career were more humble.

Early Years

Though he has often mistakenly been called an American, William Hale was born in Colchester, Essex County, England, on 21 October 1797. In fact, it is mentioned in one local history and has always been a family tradition (though not a proven one) that he was descended from the great 17th century Lord Chief Justice of England, Sir Matthew Hale. William's father was a baker and his maternal grandfather, William Cole, a gifted educator who was also a writer on such diverse subjects as his own theories on comets to algebra and church music. Probaly Cole was Hale's greatest influence, if not his teacher.

Hale, in any event, showed an early penchant for mechanics His first patent, taken out in 1827, was for *Improvements in Propelling Vessels* and was claimed to have been the first design of an internal-screw ship in England. In two ways this patent may be said to have contributed to the later invention of Hale's spin-stabilized rockets. The first was in the utilization of the 2,000 year old principle of the Archimedian screw as a crude form of jet propulsion. Water was sucked into the vessel and discharged in order to drive it forward on Newton's Third Law of Motion. The inventor thus showed an early insight in jet propulsion and in the same classic principle which explains the motion of rockets. The second connection between Hale's first patent and his rockets was his study of the dynamics of a revolving screw through a fluid.

By 1832 a paper on Hale's vessel was read before the Royal Society in London by one of the Society's members, Richard Penn. A clockwork powered model was also built and tested before King William IV and Queen Adelaide on Virginia Waters in September of that year. Hale also won the first class Gold Medal from the Royal Society of Arts in Paris. He afterwards submitted this promising invention to the Admiralty but by his own admission, lost interest and from about 1839 he began to pursue 'ordnance matters', and eventually, rockets.

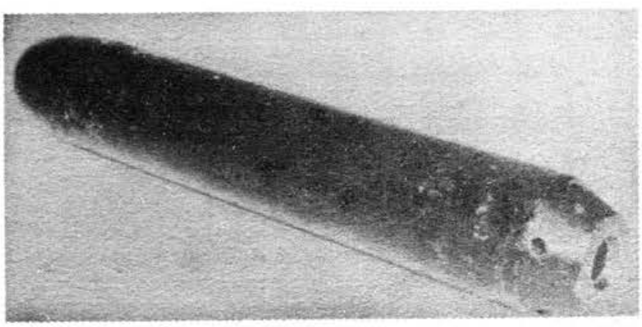
In the interim, several more patents followed, all in some way which could similarly have prepared Hale to arrive at his rotating rocket and hydraulic rocket press. These included an improved windmill, a rotary engine and a method of producing gas in 'aerated liquors'. The latter specification was taken out in partnership with George Purt, a soda-water manufacturer of Saint Mary-at-Hill, London.

About 1835, presumably to be close to Royal Navy officialdom in order to promote his boats, Hale had moved to Greenwich. It was thus, when he took up interest in ordnance, that he pulled up his roots again and moved to premises near the Royal Arsenal in Woolwich. Here he became associated with Edward Dell, a local wine merchant who had apparently formerly worked in the Arsenal's Royal Carriage Department and who had acquired enough generalized knowledge to consider himself an ordnance expert. He soon talked Hale into what proved to be a deceptive partnership in an improved gunpowder case. Though joint patents were taken out in England and France, Dell privately made a contract with someone in the Arsenal to purchase 'Dell's Patent Powder Case' with Hale losing £500 in the deal.

As it turned out, Hale gained from this affair in another way. The gunpowder case was an improvement of an idea worked out many years before by the inventor of the Congreve rocket, Sir William Congreve. Hale thus became fully aware of Congreve's achievements, particularly in rocketry, and immediately sought to make his own improvements.

Original pattern Hale 10 pounder rocket of 1844. 18.75 in. long by 3 in. diameter.

Science Museum, London



* *A longer version of this paper was presented at the 13th International Congress of the History of Science, Moscow, August 1971.*

† *National Air and Space Museum, Smithsonian Institution, Washington, D.C. U.S.A.*

Rocket Testing

He first set about establishing suitable testing grounds, a problem that has plagued many similar early rocket pioneers. In his day it may have been worse. He complained, for example, of difficulty finding 'an extent of ground over which to fire, quite free from buildings and cattle'. It is not revealed in any of the extant records how many livestock he stampeded nor how many landlords he startled, but it is known that his private experiments forced him to move on no less than 10 occasions.

By 1843 he made sufficient progress, he later wrote, 'that the use of the Stick (*sic.*) of the rocket could be dispensed with, I (then) addressed the Board of Ordnance.......That was in September'. Other stickless rockets had been tried but none looked so promising as Hale's pattern. The Government therefore ordered further trials to be made, though at Hale's expense. This arrangement was to persist for many years before the British finally agreed to purchase the rockets. Hale complained bitterly that the Government always treated him unfairly, that they had in fact used his rockets in several campaigns, such as the Crimean War, but never fully compensated him. These complaints were perhaps vindicated as not until some 26 years later, in 1867, did the Government officially purchase Hale's invention for £8,000.

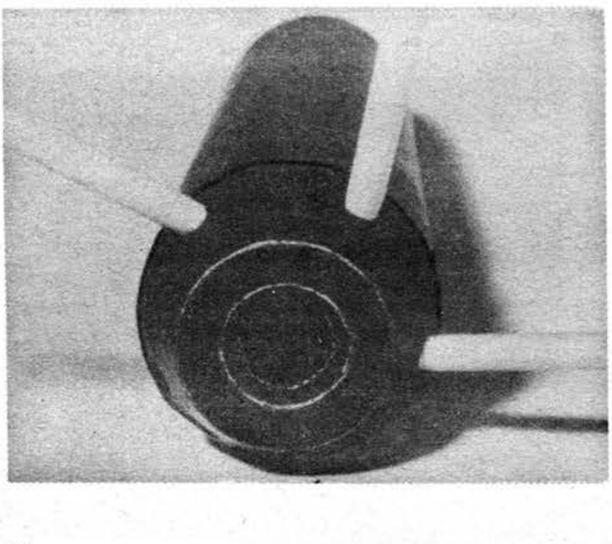
In the meantime, Hale and his sons (he married about 1828 in Colchester to Elizabeth Rouse and by her had two daughters and two sons), as well as some designated 'agents', negotiated sales with many other nations. The Americans purchased the secret – as well as his hydraulic rocket presses – and used Hale rockets during the Mexican War of 1846-1848 and during the Civil War, 1861-1865.

One frightful test was, in fact, conducted by Hale's American agent before President Lincoln and some leading cabinet members in November, 1862. The rocket exploded very near the President, almost changing the course of American history!

The Austrians adopted the rockets and used them extensively. The Prussians, Swiss, Danes, Canadians, Portuguese, Brazilians, Cubans and others likewise adopted them. The French and Russians witnessed tests from time to time, but did not find them satisfactory. Overall, however, William Hale's rockets were a success. Undoubtedly the pinnacle of his fame was in 1853; though it was an infamous one.

Sticks protruding from the rear apertures show that they are canted to produce rotation upon combustion.

Science Museum, London



The Hungarian Episode

It was then that Hale was accused of manufacturing war rockets for the revolutionary plots of the former Hungarian leader who was then living in exile in England, Louis or Lajos Kossuth. The scandal reverberated throughout Europe and almost ruined the inventor. It was apparently started by a disgruntled employee of Hale who had worked briefly at his rocket factory at Rotherhithe, off the Thames.

This employee was a former major of the Hungarian Artillery named August Usever who had been hired by Hale through Kossuth. The exact relationship between the inventor and Kossuth is still clouded in mystery, though some documents recently found in the Ferenc Pulsky Archives in Budapest reveal that Hale did indeed negotiate sales of his rockets to the Hungarians. In any event, it appears that Usever informed the British Government that Hale's factory was secretly making rockets for Kossuth's revolutionary plots. The Government proceeded cautiously and assigned a detective wearing a different disguise every day to watch the factory. Yet, it was only proven that Hale had illegally been keeping a certain quantity of gunpowder and weapons within the city of London.

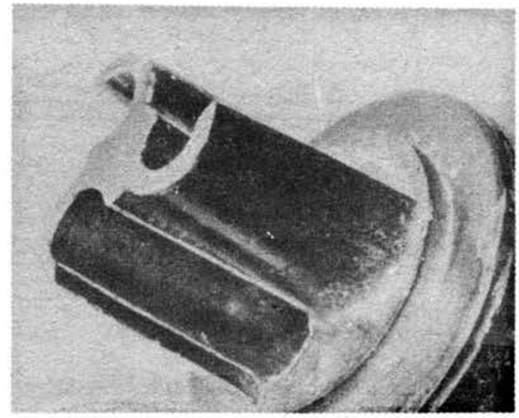
Consequently, on the morning of 13 April 1853, the detective and the superintendent of the Thames Police visited the Hale establishment and later arrested the inventor and one of his sons. About 1,500 loaded war rockets and several barrels of gunpowder were also siezed and sent by boat to the Royal Arsenal which was close by. Kossuth admitted he knew Hale and that he thought highly of the invention, but emphatically denied any revolutionary plot or that Hale was for any reason making rockets for him. Nonetheless, the scandal struck newspapers throughout Europe and was made even more shocking when – though it was by sheerest coincidence – it was discovered that some known revolutionists in Prussia were at the same time being arrested for clandestinely operating a gun *and rocket* arsenal in Berlin.

A trial was held for the Hales at the Bow Street Police Court in London and was reportedly 'crowded to excess on the occasion'. The case was also hotly debated in Parliament, one M.P. calling it 'The Rotherhithe and Kossuth Mare's Nest'. Viscount Palmerston, the Home Secretary and soon to be the Prime Minister, called for 'moderation' and 'truth'. Moderation prevailed. Despite the sensationalism, Hale and his son were only charged with illegally keeping an excessive quantity of gunpowder under an act of George III. The Hales pleaded guilty and after paying the fines were practically forced into bankruptcy.

The Crimean War intervened and Hale recovered his fortune by going to the Crimea and selling his remaining war rockets to the British fleet stationed there. Though the British used mostly Congreve stick rockets in the war, there were also a few Hales and they were fired at Balaklava and elsewhere.

Perfected Rocket

Following the war, Hale continued, as always, to constantly perfect his rockets and to take out other patents. Some of these inventions significantly included improvements in rolling iron and steel and reflect the application of the latest advances in metallurgy and manufacturing to



Hale war rockets. Left, 24 pounder, without tail-piece; centre, tail-piece for same; right, bottom, Hale 10 pounder design of 1844. Right top, Hale 24 pounder of about 1862-1865, the finalized or 'classic design'. Artillery Museum, Woolwich, England.
Top right, tail-piece of 24 pounder rocket. Science Museum, London.

rocketry. From his first rocket patent (No. 10,008) granted on 11 January 1844, Hale went through several major modifications of his rockets inside and out and in the period 1862-1865 arrived at the 'classical' design. This all metal rocket (save for a hardwood core in the head) utilized the propellent gas for both propulsion and stability by a special tail-piece threaded to the base. It consisted of 3 curved and slightly inclined metal vanes, so that the exhaust gas itself caused the spinning of the rocket through its axis.

Hale's hydraulic press – which he developed but did not invent – compressed the powder in a far denser matrix than was thus far possible. This type of machine had been used experimentally in France as early as 1834 by Artillery Captain L.C.H. Le Chevallier, though Hale exclusively used this method and was therefore responsible for introducing it into those countries that adopted his rockets. Prior to the hydraulic press, rocket propellent was compressed into rockets by a muscle-operated pile driver known as the 'monkey press'. It was slow, inefficient – and dangerous. Higher specific impulses and reliability in rocket performance resulted from the hydraulic press, besides greater speed and safety in manufacture.

British Naval Rocket Brigade firing Hale war rockets in the Abyssinian War, 1868. From *'The Illustrated London News'*, 11 July 1968, p.32.

In 1867, as mentioned earlier, the British Government officially adopted Hale's rockets and they entirely superseded the Congreve type. During the same year they were also displayed by both the English and the Austrians at the International Exhibit in Paris. And in the following year they were employed in the Abyssinian War, the first of many colonial campaigns in which Hale rockets were successfully used.

Hale rockets were, in fact, officially retained in the war material catalogues as late as 1919, though it appears that their last service on the field of battle was about 1899. Possibly this was in Sierra Leone, West Africa, when Lieutenant V. Buckland's Royal Navy 'rocket detatchment' fired some in a colonial campaign there during February to May of that year. Specimens of Hale rockets can be seen today at the Rotunda, Woolwich. Some can also be seen at the U.S. Army Museum, West Point, New York, and some were formerly found in the Herresgeschichtliche Museum in Vienna.

Three years after his rockets had finally been accepted by the British Government, on 30 March 1870 William Hale died. His grave site, with a newly erected marker put up by his great grand daughter, can be viewed at the Old Brompton Cemetery, London. And what may have been his last home still stands at 9 Edith Terrace, Edith Grove, Chelsea. Unfortunately, no portrait of Hale has thus far been located and the writer is very desirous of locating one.

One hundred years after he died, the International Astronomical Union chose his name to be shared with the astronomer George Ellery Hale (but to whom he is not related) to designate the Hale crater on the Moon (90°E, 74°S). Thus, the name of William Hale and his contributions to the history of rocketry have been fittingly commemorated.

REFERENCE

1. Winter, Frank, H., 'Sir William Congreve: A Bi-Centennial Memorial', *Spaceflight,* September 1972, pp. 333 - 334.

(The Editor would welcome any further historical material relating to Sir Wliiam Congreve and William Hale. There may, for example, be correspondence and other written material relating to pioneer rocket experiments which have not yet found their way into national archives.)

THE URGENT NEED FOR A UNITED KINGDOM SPACE AUTHORITY

The following Statement on 'The Urgent Need for a United Kingdom Space Authority' was forwarded to the Prime Minister on 2 November 1972. Copies were also distributed to Government Ministers concerned with Space affairs and to certain Members of the Opposition.

THE URGENT NEED FOR A UNITED KINGDOM SPACE AUTHORITY

The Council of the British Interplanetary Society once again urges H.M. Government to recognise space exploration and utilization as an important part of national policy.

Apart from the opportunity it provides for expanding whole areas of scientific knowledge, Space has already entered important commercial and social fields which are vital to the continued growth and development of nations. The areas most directly affected include inter-continental communications, direct broadcasting, education, aeronautical and marine communications, navigation, meteorology, agriculture, natural resources and pollution control.

The Society first urged the creation of a UK Space Authority to co-ordinate national space effort and ensure adequate representation in international programmes, in a Memorandum to H.M. Government in April 1965. The same basic proposal has since been repeated by other bodies (most recently in the Fifth Report of the Commons Select Committee on Science and Technology*), but still there is no indication that such recommendations will be acted upon.

The B.I.S. considers that the time is long overdue when UK space affairs should be placed, once and for all, under central direction.

The Present Situation in the U.K.

In this country, space responsibilities have traditionally been divided between a number of Ministries, on the basis of 'user' interests (Fifth Report of the Select Committee on Science and Technology, para. 8). There is not a British space programme as such, but only an assemblage of user projects co-ordinated by some undisclosed Cabinet machinery, which does not lead to any publicly discernible positive line of policy in relation to space as a whole.

The Government administrative machinery has recently been made even more difficult by implementation of the Rayner Report which actually increased the fragmentation. (The former Space Division of the Ministry of Aviation Supply was divided into three branches of the Department of Trade and Industry and the Ministry of Defence – each with its own separate Director, staffs, and all the duplication this entails).

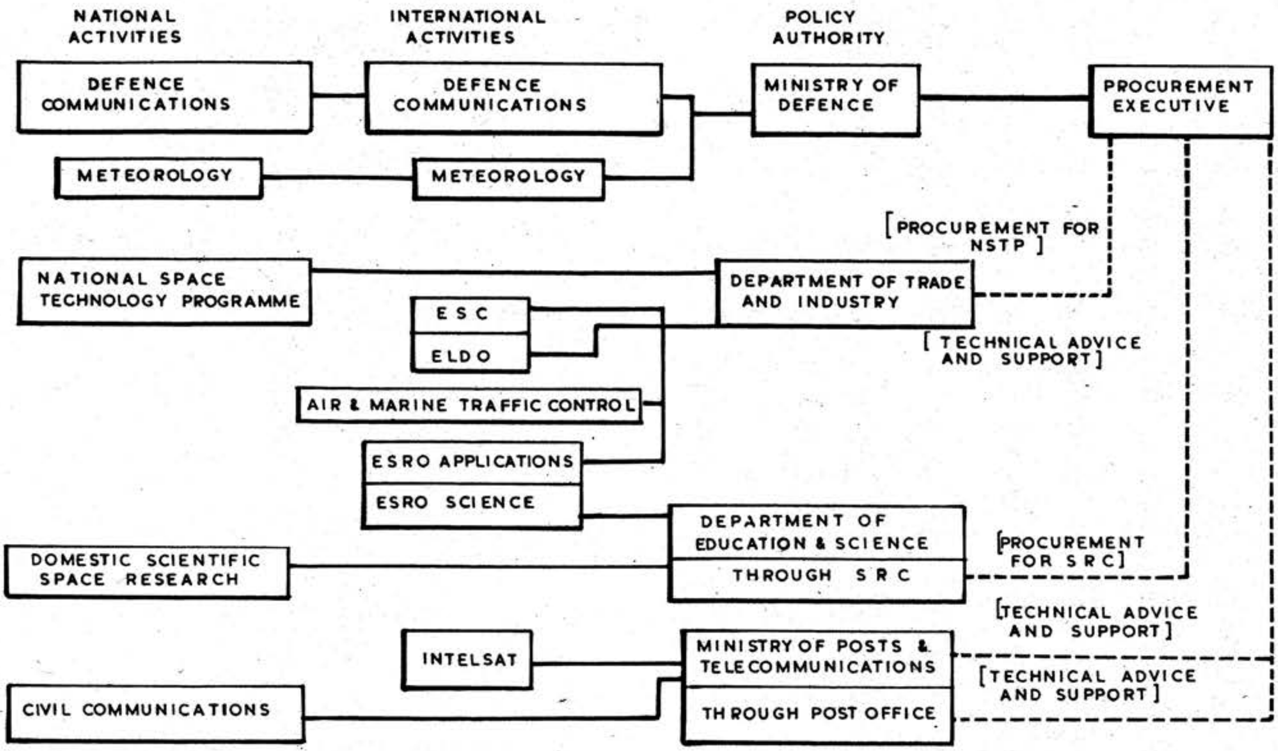
It is instructive to recognise how this division came about. The Rayner Report† contains this statement:

"**Space.** *The Government's policy responsibilities for space questions involve a number of Ministries and Departments; these will continue to be co-ordinated through the normal Cabinet machinery. The particular responsibilities of the Ministry of Aviation Supply will be redistributed. Technical and Managerial responsibility for research, development and procurement will be transferred to the new Procurement Executive. Its non-defence and financial responsibilities, including those for European space programmes and the United Kingdom Space Technology Programme, will go to the Department of Trade and Industry. The Ministerial Aerospace Board will be available to co-ordinate space procurement activities between user departments and the new Procurement Executive".*

It continues:

"Work on space by the Ministry of Aviation Supply at the moment is the sum of a number of different requirements..... we consider that the technical and managerial responsibilities for this work should remain with the rest of the procurement organisation. As for the policy responsibilities, these should remain, in most cases, with the customer department, e.g. the Ministry of Defence for the Skynet replacement, the Science Research Council for research satellites. Responsibility for co-ordinating space procurement policy should lie with the Ministerial Aerospace Board, reinforced for this purpose by the Secretary of State for Education and Science and the Ministry of Posts and Telecommunications, and the interdepartmental machinery dealing with space policy should be reviewed to take account of this. The areas of difficulty would be policy responsibility in relation to European Space Programmes and for the United Kingdom Space Technology Programme. As we see it, this work is, in essence, similar to research and development work on civil aircraft, and for the same sort of reason we recommend this policy responsibility and with it financial responsibility should go to the Department of Trade and Industry".

It would be difficult to conceive a more cumbersome structure than the one at which the U.K. has now arrived. No other country involved in space activity submits itself to such a handicap.



Departmental Interests in U.K. Space Activities (after disbandment of Ministry of Aviation Supply in 1971).

The Situation in Other Countries

The new management techniques evolved by the U.S. National Aeronautics and Space Administration, which has its own budget approved annually by Congress, have become a by-word for efficiency and effective cost-control.

In France, the need for a national organisation to plan, integrate, manage and develop space activities was recognised several years ago by the establishment of the Centre National d'Etudes Spatiales (CNES).

This organisation has helped enormously to stimulate French initiative in many areas of space science and technology, including national programmes which have resulted in the orbiting of a number of satellites, initially from Hammaguir in the Sahara and more recently from the national launch centre established at Kourou in French Guiana.

The CNES has also played a vital role in establishing important international programmes with the United States and the Soviet Union. Not only has this enabled France, at modest cost, to have small satellites launched by these countries but it has given her scientists very great opportunities in space exploration. For example, a French laser reflector has been placed on the Moon aboard the Soviet Lunokhod remote-controlled roving vehicle, and a solar radiation experiment has been carried into orbit around Mars by the Soviet automatic interplanetary station Mars 3. In the applications field, a Franco-Soviet agreement has allowed France to participate in experiments with Soviet Molniya communications satellites.

In West Germany the Ministry of Science and Education is able to take the principal role in space policy. Currently, it is supporting a major space exploration project with NASA designed to allow a spacecraft, Helios, to penetrate within 23 million miles of the Sun. Apart from work on small satellites, the Ministry is also supporting advanced hypersonic research with sub-scale lifting bodies and winged vehicles.

More recently, India, a nation striving to apply satellite techniques for social welfare (e.g. spreading basic education to rural communities by direct-broadcasting satellites) has established a Ministry of Space to manage national and international space affairs.

Proposal for a central U.K. Space Authority

In contrast to the position in these countries, the U.K. organisation, predicated as a means for ensuring that space is not pursued for its own sake, is in fact a recipe for piecemeal and incoherent development and the short-term saving of money at

all costs. Projects come into being, if at all, solely on the individual criteria of customer Departments (e.g. profitability to the Post Office, cost-effectiveness to the Services) with little weight attached to the integral space capability or to the long-term factors.

If, as in the case of Earth resources, the user interest in space is spread over fields of several Ministries, it may never get off the ground at all. If it is a question of national technological capability, as in the national space technology programme, the issue drifts on with political decisions valid for only a few months at a time.

The degree of ministerial involvement is far greater in space matters than in other areas of comparable expenditure. What is needed is an authority with a non-political Head, charged with a positive function in respect of space. Its primary task would be to look at the situation as a whole, taking long-term considerations of the national interest fully into account and acting within a budget assigned to it, supplemented by user contributions.

B.I.S. Recommendations

The Council of the British Interplanetary Society takes the view that there is now an overwhelming case for H.M. Government to set up immediately a National Space Authority charged with the following responsibilities:

(1) Overall planning and co-ordination of scientific, commercial and social aspects of space development.
(2) Liaison with appropriate Government departments traditionally responsible for the corresponding terrestrial activities (e.g. telecommunications, meteorology, environment, aeronautical, marine, education, etc.).
(3) Liaison with international agencies.

The function of the Authority would be to co-ordinate and administer the technical arm of space development in order to achieve the most cost-effective U.K. contribution.

* *'Fifth Report from the Select Committee on Science and Technology, Session 1970-71, United Kingdom Space Activities', HMSO, £3.15.*

† *'Government Organisation for Defence Procurement and Civil Aerospace', HMSO Cmnd. 4641. 35p.*

SOCIETY NEWS

Ariel-4 and Prospero

Nearly 60 participants assembled for the one-day meeting on *Ariel-4 and Prospero* held in London on 27 Sep 1972, to hear a useful and informative survey of these facets of the British Space Programme.

The morning session was devoted to Prospero, the afternoon to Ariel-4. Throughout the meeting an interesting display was mounted, including two half-scale model satellites, solar cell modules, thermal surface experiment panel and a micrometeoroid detector, together with a variety of components of the data conditioning system.

Prospero

Following a welcoming Address by the Society's President, Professor G. V. Groves, the first paper by H. J. H. Sketch, outlined the Prospero spacecraft and provided a useful background for the following papers. Three advances in commonly-used equipment were emphasised, i.e., the data conditioning system, power supply and the sensor system; this last consisting of two slit sensors and an albedo sensor.

Mr. F. C. Treble then described the technological experiments performed with Prospero. The thermal control experiment was covered in some detail; the aim of this was to space-test the stability on a number of surface finishes which might be used to control spacecraft internal temperatures. In all, 19 different surfaces were used. Some results over the 225 days of data collection were produced; it was noted that, of a number of white paints included, the acrylic ones showed most degradation.

The solar cell experiment tested thin cells and various coverslips. The short-circuit current from the thin cells showed an apparent logarithmic degradation, although – unexpectedly – that for the 1 ohm cm cells was less than for the 10 ohm cm cells. There was no discernable degradation of open cell voltage.

The automatic checkout system for the spacecraft was covered by Mr. B. R. Young. The requirements for checkout were analysed and the necessity for conducting checkouts from the laboratory or mobile stations considered. The overall task was to split between 'hardware' and 'software'.

Mr. D. H. Hardy reported on Prospero Orbital Operations. After 11 months, the satellite continued to function correctly; indeed, in October, tests would be carried out on the still unused automated emergency procedures. A noteworthy point was the remarkably fine performance of the endless tape recorder.

Dr. D. K. Bedford reverted to the scientific side by describing the micrometeoroid detector aboard the satellite. Background information was given, the methods for detecting and measuring impact flux, together with some preliminary results.

This part of the meeting was concluded by R. Staniforth with a Status Report on the X-4 satellite.

Ariel-4

Three main papers were presented on Ariel-4 technology, including a general review of the satellite and its systems, and a description of pre-launch operations.

The Electron Density Experiments onboard was covered by Dr. C. V. Goodall and, as a new departure, management aspects were described by Mr. R. F. Maurice.

To conclude, a paper by D. J. McLauchlan described work carried out in the development of the UK5 satellite.

Arrangements are being made for the technical papers to appear later in the Society's *Journal*. The Management paper, will, however, appear in a special issue of *JBIS*, which will feature other contributions on problems involved in the management of space projects.

Bronze Medal Awards Meeting

'Time is running out very rapidly for Europe to work with NASA in the Post-Apollo programme which today essentially means the sortie module', Arnold Frutkin told the Society on 4 October. 'Such is the impetus of our own programme planning that the deadline is barely a month away'.

Mr.Frutkin was speaking at University College after receiving a B.I.S. Bronze Medal in recognition of outstanding contributions to international collaboration. As Assistant Administrator of International Affairs, NASA, he is directly concerned with US/European negotiations.

Europe, he said, faced a dilemma in space. It could decide to work on a regional basis of self-sufficiency, or it could become dependent in some measure on the United States. Although the Post-Apollo invitation to Europe had shrunk in scale from the space tug, sortie module and significant elements of the shuttle, what was left was now essentially the scientific payload carrier or sortie module. The tug had disappeared because of NASA's recognition that this was 'a difficult concept to design in our own terms and was likely to become a source of difficulty rather than the subject of congenial collaboration. Its withdrawal had brought no protests from Europe – there had been no comment whatsoever.'

The sticking point for Europe on Post-Apollo was launch assurances. Mr.Frutkin said the concern that had been expressed was quite understandable but it was unrealistic to expect any nation to give unqualified assurances of this kind. What the United States had done was to assure Europe that launch facilities would be available for peaceful purposes and any applications which did not conflict with established international agreements. Judgement would still be exercised in the launching of payloads, e.g. regional communications satellites which might conflict with Intelsat even if that grouping expressed a negative view.

On the programme itself, Mr.Frutkin said 'a 10% or 5% or 4% European participation did not warrant 50% access to 'the total pool' of Post-Apollo. There was also a difference in approach between the two continents on R & D. The tendency in the United States was to 'design as we go'. Europe preferred to wait until all t's were crossed and all i's dotted, with all the Francs in the right place, before decisions were made.

It would be presumptious of me to offer advice, Mr. Frutkin went on, but a crucial decision has to be faced. Much depended on how much money Europeans were prepared to put into space work. From that decision followed the choice of developing launchers and/or payloads. A balanced programme of European launchers and satellites, including the cost of keeping launch crews in being, serving member States of ESRO and ELDO, would incur considerable expenditure. Launcher development might cost $200 million a year for a number of years. Ten payloads a year would cost between $350-500 million a year on top.

If Europe was not prepared to make this 'value judgement', there was the opportunity of 'throwing in with us.' Reason dictated that Europe would be the junior partner in any such arrangement. But proportionately the junior partner would stand to gain more than the senior partner because of the wide access that would be obtained in a manned re-usable launch system.

William H. Stephens, the former Director-General of ELDO, who also received a B.I.S. Bronze Medal for outstanding contributions to space collaboration, said there was considerable frustration about the slow progress Europe was making

Left, Mr. Arnold W. Frutkin, Assistant Administrator for International Affairs, NASA Space Academy.
Right, Dr. William H. Stephens, formerly Director-General European Launcher Development Organisation.

over Post-Apollo. Although the amount of work Europe was being asked to do had diminished, the sortie module was still on offer and awaited European political and financial decisions. In his opinion it was a most important part of the Post-Apollo programme 'and we could make use of it for our own experiments.' We should make up our minds to take this one piece, he said, and make a brilliant success of it.

His advice to Europe was to get cracking on applications cashing in on the launch vehicles we had – Blue Streak/ Europa II – and also 'Get rides from NASA while awaiting the shuttle.' He had no sympathy for those who wanted Europa III.

'Get on with the satellites themselves: applications loom large in Earth resources, communications and many other fields! We should design, develop and use satellites and find political agreement with NASA on launchers.

Dr. Stephens hoped there would be acceleration in reaching decisions in Europe. 'One day', he said, 'there will be really big developments coming from space investigations like modifying weather. We should not wait and let Russia do it for us!'

Film Show, 4 Oct. 1972.

Nearly 200 members and guests stayed on for the Film Show which immediately followed the Honours Meeting on 4 Oct. 1972.

The programme began with *Skylab,* the most recent film available in the Society's film library, which described us all as passengers on a lonely (Earth) spaceship and gave as its theme the object of extending man's capability for staying in space.

The first Skylab will be launched in 1973 with a Saturn V, in which the 3rd stage has been replaced by Skylab itself. This will be followed by 3 Saturn 1B's (the first going up on the following day) each containing a 3 man crew in an Apollo type craft, suitably adapted for docking. This will mean that Skylab becomes operational on 3 different occasions, remaining empty between-times.

After pictures of the launch,the film then concentrated on the crew facilities and crew training. Eating seems to be just as for airline passengers, with apparently little regard for the effect of crumbs, etc., on the Skylab environment. Sleeping will be in the 'vertical' position: shoes will hook into a mesh to provide body restraint. About 50 scientific objectives will be covered in each mission.

Throughout the mission, extensive studies of the Sun and its chromosphere (up to about 2½ million miles out) will be made, with a watch kept, especially, for solar flares. Detailed Earth observations will be made,first to discover the best film and filter combinations to be used. Single snaps will cover an area of 64,000 sq. miles in 5 different wavelengths.

The second film, *Apollo 16 - Nothing so Hidden,* continued the epic story of the manned flights to the Moon, this time the journey of Young, Duke and Mattingley in Orion and Casper.

The film began with problems during the last hour of the count-down, and with the actual launch passed over somewhat lightly, unlike earlier films which magnificently captured, in close-up, the roar of the engines at full power. Then came the splendid undocking sequence in lunar orbit, followed by the news of the non-burn in lunar orbit due to uncontrolled oscillations. Once this problem was satisfactorily resolved, the 'Go' for landing was given, with excellent use made both of film returned to Earth and recordings made from the colour TV transmissions *en route.* The three EVA's were covered in some detail, with more drama when Duke dislocated the cable to the heat-flux probe.

Film of the excursions in the Lunar Rover showed some of the frequent stops made to carry out scientific observations, with the part played by TV in enabling Earth-bound scientists to direct operations amply displayed.

Lunar surface shots ended with lift-off, followed by rendezvous in lunar orbit, the homeward journey, a 'fireball' re-entry and a perfect splashdown.

The interlocking of the adventure of exploration and the quest for knowledge is conveyed by many scenes of scientists who took part in the project. It is always good to glimpse something of the huge team which lies behind theses successful missions, although we all tend to travel with the astronauts themselves!

OBITUARIES

We greatly regret to record the deaths of the following members:-

Geoffrey Douglas David (Member) an engineer who joined the Society in 1969, Mr. David was 32.

Hector Jacinto Medici, aged 69,a Member of the Society since 1966. Prof. Medici enjoyed a long teaching career. He was not only a Civil Engineer but also a Professor of Mathematics at the Colegio Militar de la Nacion, in Argentina.

Douglas Donald Smith, a Member of the Society since 1968 and who died at the age of 23, following a second heart operation.

Tom Watson, aged 59 (Member) formerly in the Experimental Aircraft Development Department of BAC, Preston. Mr. Watson joined the Society in 1967.

CORRESPONDENCE

Gravity and the Expanding Universe

Sir, The recent correspondence in your columns contains some interesting ideas, particularly regarding the interaction of matter and anti-matter, but clearly there will continue to be wide differences of opinion until a great deal more precise observation has been done. Meanwhile the following model might be a useful addition to those already under discussion.

Two concentric cosmic spheres of the same diameter, one of matter and the other of anti-matter. In overall diameter neither sphere is expanding or contracting; but the material sphere is in a steady state of continuous outward flow, and the anti-material sphere is in a steady state of continuous inward flow.

A particle of matter starting almost at rest near the cosmic centre is accelerated outwards by (a) the repulsion of a concentric body of anti-matter, and (b) the attraction of a peripheral envelope of matter. Such a particle of matter moves outwards on a straight radial line, accelerating under the steady influence of repulsion from the centre and attraction from the periphery until it attains nearly the speed of light. At this speed its mass becomes so great that it collapses under its own gravitation, leaving a 'black-hole' in space.

This happens to all matter which has not previously collapsed, at a fixed distance from the cosmic centre, because the acceleration of all particles and accumulations of matter under the fixed influence of cosmic repulsion and cosmic gravitation will be similar.

There is thus a fixed 'Cosmic radius' and a 'Periphery of absolute gravity' which is like a hole-in-space formed in the shape of a spherical envelope.

Holes-in-space formed by the collapse of material bodies within the cosmic sphere will move outwards with the same speed and acceleration as the body at the instant of collapse, to become integrated with the periphery of absolute gravity. The anti-matter resulting from the collapse will instantly move inwards with the same speed as the collapsed body was moving outwards.

All matter which reaches the cosmic periphery collapses under its own gravity and is translated into anti-matter which is instantly travelling back towards the cosmic centre at nearly the speed of light, but slowing down as it moves inwards. Somewhere near the cosmic centre, in a vast body of anti-matter, individual particles or pulses of anti-matter react with similar particles to translate into particles of matter. These are repelled by the control body of anti-matter and start outwards on their journey to the cosmic periphery, thus continuing the steady process of outward-inward/matter-anti-matter flow.

To an observer in the 'matter' state the system would appear to be continuously expanding with all other bodies receding, and those furthest away receding with greatest velocity.

The opposite would be the case for an observer in the 'anti-matter' state.

The outward streams of matter and the inward streams of anti-matter are deflected from each other by gravitational repulsion and 'wobble' on their direct radial tracks, but collisions might occur perhaps when particles are ejected at great velocity by violent material or anti-material reactions within their own systems. If this happens,particles of matter and anti-matter interact to bring about their annihilation.

If such annihilation is absolute,certain conclusions are suggested: (a) the system is now in a 'steady-state' decline. (b) The system started with a 'big-bang', such as the violent separation of an intimately mixed and condensed body of matter and anti-matter. (c) The system will become extinct when the last particle of matter and the last particle of anti-matter interact and annihilate each other.

Many more events suggested by currently accepted theory and observed phenomena can be made to fit exactly into this model, but it is hoped that the above outline will serve to stimulate further thought and discussion.

A. H. WALKER

The 10th Planet

Sir, Whilst agreeing that the name of Janus has already been used, I cannot agree with Ian Ridpath's comments on 'retrograde orbit with 60° inclination'.

Having read Brady's paper, the cyclic disturbance of Halley's Comet is only too obvious. That the best model to explain these disturbances resulted in these unusual parameters is not entirely a matter of faith.

There is no denying that the apparent order near the centre of the Solar System is highly disturbed and ragged towards its edges. Reference the anomalous tilt of the axis of Uranus, the retrograde motion of Triton (major satellite of Neptune), and the very peculiar orbit of Pluto, I see nothing unusual in Brady's figures for the 10th planet. Indeed it is possible that a collision or series of collisions of proto-planet material will produce these anomalies.

The gravitational field of the Sun at these tremendous distances is weaker and whilst holding a body in a stable orbit may not necessarily dictate that the orbit must be normal.

Good examples of high eccentricity retrograde orbits already exist in miniature system form for the outer satellites of Jupiter, Saturn and Neptune. When it is possible to use larger telescopes above the atmosphere I have no doubt that further eccentric retrograde minor satellites will be revealed.

Dole in recent work showed that in some of his computer models of Solar System formation, one or more planets had retrograde motion.

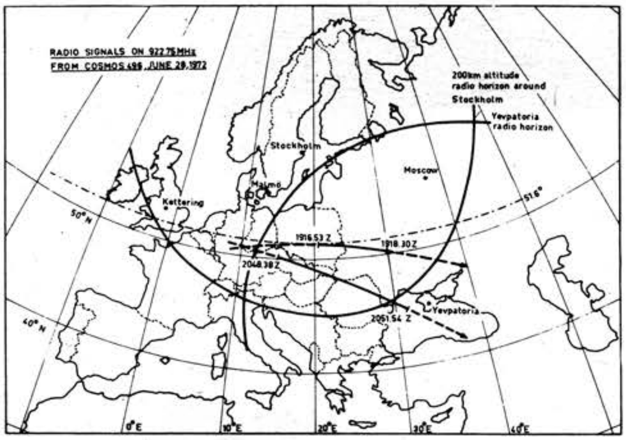
We tend to regard the innermost parts of the Solar System as 'norm'. In doing so, we are trading on very little knowledge of how big the Solar System really is – and Brady suggests the suspicion of yet another planet beyond the 10th.

The predicted orbit of the 10th planet already doubles the size of the Solar System, and another major planet could double it yet again.

ANTHONY T. LAWTON

Tracking Cosmos 496

Sir, On 26 June 1972, Cosmos 496 was launched from the Tyuratam cosmodrome in Kazakhstan. The launch took place at 1450 Z and resulted in the initial orbit having a 51.61° inclination, 89.53 min. period and ranging between 187 and 321 km. The Soviet new agency *Tass* announced that the satellite carried 'a radio transmitter operating on a frequency of 20.008 MHz; a radio system for accurately measuring the elements of the orbit and a radio-telemetric system'. All systems were said to be 'operating normally'.



The orbit and the HF radio frequency of Cosmos 496 were very similar to those used by Soyuz-type spacecraft. Working on this assumption several amateur space-tracking stations tried for several days following the launch to pick up Soyuz-type signals (CW/PDM-Pulse Duration Modulation) on 20.008 and 15.008 MHz (Soyuz shortwave frequencies) but without success.

Soyuz and Salyut spacecraft are known to use the microwave frequency 922 MHz for telemetry and tracking. Therefore, an attempt to track Cosmos 496 on this frequency was made. Mr. Geoffrey Perry, leader of the Kettering Grammar School Space Tracking Group, sent me orbital predictions for Cosmos 496 by telephone in the afternoon of 18 June 1972. Using these predictions I successfully picked up telemetry and beacon signals from Cosmos 496 on 922.75 MHz at 1916.53-1918.30 Z on 28 June 1972 at my tracking post in Taby outside Stockholm. The signal, which contained three carriers and high-speed commutated telemetry sidebands, was again picked up at 2048.38-2051.54 Z on 28 June.

The radio horizons from Stockholm and Yevpatoria (the main Soviet space tracking station situated on the Crimean Peninsula) for a satellite at approximately 200 km altitude are plotted in Fig. 1, together with the ground tracks of Cosmos 496 during the reception periods. It is clear from this figure that the signals from the satellite started when it came into view from Yevpatoria and disappeared when it went down below the horizon in Stockholm. Optical sightings of Cosmos 496 were also made from several points in the UK, but no firm estimates of the size of the spacecraft or its booster were possible from these observations.

However, several facts indicate that Cosmos 496 was a Soyuz-type vehicle. The inclination, perigee, HF frequency and microwave signals agree with what one could expect from a Soyuz flight. The apogee is higher than normal for a Soyuz orbit, but if Cosmos 496 was a test of a redesigned Soyuz some of the crew and docking equipment may have been omitted. This would mean lower payload weight and hence a higher orbit.

Cosmos 496 re-entered the atmosphere and landed in the Soviet Union at approximately 1430 Z on 2 July 1972.

I wish to express my thanks to Mr. G. E. Perry for providing orbital predictions for Cosmos 496, to Mr. Richard S. Flagg of Gainesville, Florida for making microwave receiving equipment for the 920-960 MHz range available to me and to Miss Inger Albrecktsson for preparing Fig. 1.

SVEN GRAHN, Civ. Ing., A.F.B.I.S.
Institute of Meteorology, University of Stockholm, Sweden.

WANTED: *Spaceflight* back numbers before January 1972
Contact: Hurst, 13 Valley View, Clutton, Bristol.

A Selected Reading List

Many of the items listed are available on loan through the Society. Requests should be sent to the Executive Secretary enclosing 25p (minimum postage rate) for each book or report desired. Items are forwarded only on the understanding that the maximum loan period of one month will not be exceeded. This must be strictly adhered to, to avoid inconvenience to other borrowers.

SOLAR SYSTEM

COMETS/METEORS/INTERPLANETARY MEDIUM

Books

Author	*Title*	*Year of Publication*
J. G. Porter	Comets and Meteor Streams	1952
U.S. Dept. of Commerce	Tables for Rocket and Comet Orbits	1953

NASA Reports

SP-78	The Meteoroid Environment and its effects on Materials and Equipment	1965
SP-135	Meteor Orbits and Dust (A Symposium)	1967
SP-150	The Zodiacal Light & the Interplanetary Medium	1967
TN-D-4284	The Explorer XXIII Micrometeoroid Satellite - Description and Results Nov. 1964-Nov. 1965	1968
TN-D-5267	The Pioneer 8 Dust Experiment	1969
TN-D-5710	Empirical Analysis of unaccelerated velocity and mass distributions of photographic meteors	1970
TN-D-6266	The Lunar Orbiter Meteoroid Experiments	1971
TR-R-322	Determination of Meteroid environments from photographic Meteor Data	1969
TT-F-100	Meteorites	1964 (Moscow 1964)
TT-F-378	Meteoric Matter in Interplanetary Space (V.G. Pesenkov 1947)	1965
TT-F-582	Carbonaceous Matter in Meteorites (Organic Compounds, Diamonds, Graphite)	1970
TT-F-599	Astrometry and Astrophysics 4: Physics of Comets	1970 (Kiev 1969)
TT-F-608	The Nature and Origin of Comet and Meteors	1970 (Moscow 1967)

Russian Reports

	Physics of Comets and Meteors	1966
	Photographic Methods in Meteor Astronomy	1964

ESRO Reports

SN-41	The Significance of Zodiacal Light Measurements by Deep Space Probes	1968
SP-54	Planetary Space Missions II – Physics of Meteorites and the Interplanetary Medium	1970
SP-55	As above: III – Electric and Magnetic Fields in the Solar Wind	1970

GENERAL

Books

Author	*Title*	*Year of Publication*
G. Abetti	Stars and Planets	1966
V. M. Blanco. *et al.*	Basic Physics of the Solar System	1961
M. B. McElroy and J. C. Brandt.Ed.	The Atmospheres of Venus and Mars	1968
K. E. Edgemont	The Earth, the Planets and the Stars	1961
S. J. Inglis	Planets, Stars and Galaxies	1961
J. H. Jackson	Pictorial Guide to the Planets	1965
G. P. Kuiper	The Atmospheres of the Earth and Planets	1947
R. A. Lyttleton	Mysteries of the Solar System	1968
P. Moore	The Planets	1962
A. E. Nourse	Nine Planets	1960
W. Page and T. Page. Ed.	Wanderers in the Sky (Planets and Probes)	1965
C. Sagan. *et al.*	Planetary Atmospheres	1971
W. Sandner	Satellites of the Solar System	1965
R. A. R. Tricker	Paths of the Planets	1967
F. G. Watson	Between the Planets	1949
N. A. Weil	Lunar and Planetary Surface conditions	1965
F. L. Whipple	Earth, Moon and Planets	1947
Lowell Observatory	The Study of Planetary Atmospheres 1952	1952

NASA Reports

SP-98	Significant Achievements in Planetary Atmospheres 1958 - 1964	1966
SP-99	Significant Achievements in Planetology 1958 - 1964	1966
TN-D-5271	Jupiter Swingby Missions to non-specific locations in interplanetary space	1969
TN-D-5284	Planetary Effects in the motion of natural satellites	1969
TT-F-502	Physics of the Moon and Planets	1969 (Moscow 1966)
TT-F-515	Physics of Planets	1968 (Moscow 1967)
TT-F-566	Astrometry & Astrophysics I: Physics of the Moon & Planets	1970 (Kiev 1968)

Russian Reports

	Physics of the Solar System	1966
	Physics of the Moon & Planets	1964
	The Nature of the Planets	1964

Communications 64-69 of the Lunar & Planetary Laboratories 1966

SPACE COMMUNICATIONS

SYSTEMS

Books

A. G. W. Cameron	Interstellar Communication	1963
R. F. Filipowsky	Space Communication Techniques	1965
	Communications Satellite System Technology (Vol.19: Progress in Astronautics & Aeronautics)	1966
F. J. Tischer	Basic Theory of Space Communications	1965
E. A. Wolff	Antenna Analysis	1966
R. E. Young	Telemetry	1963

NASA Reports

SP-69	Space Technology Vol.V:Telecommunications	1966
SP-87	Proceedings of the Apollo Unified S-band Technical Conference	1965
SP-93	Significant Achievements in Space Communications and Navigation 58-64	1966
SP-217	Optical Space Communications	1969
TN-D-4509	Lunar Far-side Communications Satellites	1968
TN-D4555	An Omnidirectional Flush-mounted microwave antenna with simple feed for use on Spacecraft	1968
TT-F-628	Broadcasting by Means of Satellite	1971

Spaceflight

Spaceflight is published monthly by the British Interplanetary Society, and is issued free to members.

Full particulars of membership may be obtained from the Executive Secretary at the Society's offices at 12 Bessborough Gardens, London, SW1V 2JJ: telephone 01-828 9371.

Correspondence and manuscripts intended for publication should be addressed to the Editor at 12 Bessborough Gardens, London, SW1V 2JJ

Opinions in signed articles are those of contributors, and do not necessarily reflect the views of the Editor or the Council of the British Interplanetary Society, unless such is expressly stated to be the case.

SPACE STUDY MEETING
Theme **Project Starship**

To be held in the Tudor Room, Caxton Hall, Caxton Street, London, S.W.1 on **10 January 1973** from 6.30 - 8.30 p.m.

A discussion meeting, initiated by Alan Bond, with contributions from other Speakers, on the propulsion requirements for an interstellar voyage. Members and their guests only.

LECTURE
Title **New Knowledge of the Sun** by Dr. J. C. Brown

To be held in the Tudor Room, Caxton Hall, London, S.W.1 on **26 January 1973,** 6.30 - 8.00 p.m.

No admission tickets are needed. Members may introduce guests.

LECTURE
Title **Studies of the Moon — 1** by Professor S. K. Runcorn

To be held in the Lecture Theatre, Royal Society of Arts, John Adam Street, London, W.C.2 on **13 February 1973,** 6.30 - 8.00 p.m.

No admission tickets are needed. Members may introduce guests.

LECTURES
Theme **Studies of the Moon — 2**

To be held in the Tudor Room, Caxton Hall, London, S.W.1 on **22 February 1973,** 6.30 - 8.30 p.m.

Two papers will be presented.

(a) Carbon Chemistry of the Moon by Dr.C.T.Pillinger.

(b) Lunar Seismology and Thermal Effects by Professor J.A.Bastin.

No admission tickets are needed. Members may introduce guests.

LECTURE
Title **New Maps of Mars** by C. A. Cross, FBIS.

To be held in the Tudor Room, Caxton Hall, Caxton Street, London, S.W.1 on **8 March 1973,** 6.30 - 8 p.m.

No admission tickets are needed. Members may introduce guests.

MAIN MEETING
Theme **Structures of Space Vehicles and Spacecraft**

To be held in the Architecture Lecture Theatre, University College, Gower Street, London, W.C.1 on **3 - 4 April 1973.**

Subject areas are as follows:–

(a) Thermal Analysis
(b) Substrates/Solar Arrays
(c) Mechanisms
(d) Fatigue Testing for Vibration
(e) Welded systems/structures
(f) Fracture Mechanics
(g) Advanced materials/techniques
(h) Quality Assurance

Offers of papers are invited.

Further details available from the Executive Secretary.

This meeting will be followed, on **5 - 6 April 1973,** with a meeting entitled 'Reinforced Plastics in Aerospace Applications' organised by the Plastics Institute. By special arrangement, those attending the Society's meeting will also be able to attend the subsequent meeting on payment of a specially reduced fee.

MAIN MEETING
Theme **Earth Observations Satellites**

To be held in the Large Physics Theatre, University College, Gower Street, London, W.C.1 on **11 - 12 April 1973.**

Subject areas are as follows:–

(1) *Advances in Earth Resources Applications*
  (a) Applications of Earth Resources Techniques (Geology, Agriculture, Marine etc.)
  (b) Development of Sensors (Cameras, IR Line Scan, Radar and Radiometry)

(2) *Earth Resources Projects*
  (a) Vehicles (Balloons, Aircraft, Rockets and Satellites)
  (b) Current & Future Projects (Skylark, ERTS-1, Skylab)

(3) *Ground Support Facilities*
  (a) Data Platforms
  (b) Data Processing (Visual Interpretation, Digital Data Processing)
  (c) Ground truth: Interpretation of results

(4) *Recent Experimental Results*
  (a) Skylark (b) ERTS-1 (c) Others

(5) *Organisation, Administration and Policy*
  (a) Management (c) Legal
  (b) International aspects (d) Economic

Offers of papers are invited.

JOINT MEETING
Theme **Electric Propulsion of Space Vehicles**

To be held at Culham Laboratory, Abingdon, Berks, on **10 - 12 April 1973.**

The following subjects will be included:–

(a) All types of electric thrustors
(b) Power conditioning, energy conversion and control of electric propulsion systems
(c) Installation of systems into space vehicles
(d) Assessment of missions pertinent to electric propulsion
(e) Testing of propulsion systems in the Laboratory environment
(f) Technologies and manufacturing techniques

Organised jointly by the Science Education and Management Division of the IEE and the UKAEA Culham Laboratory in association with the Institute of Physics, the R.Ae.S., and the B.I.S. Residential accommodation will be available at Corpus Christi College, Oxford and transport between Oxford and Culham Laboratory will be provided.

Offers of papers are invited.

Further details are available from the Executive Secretary.

LECTURES
Theme **The New Knowledge of the Sun — 2**

To be held in the Tudor Room, Caxton Hall, Caxton Street, London, S.W.1 on **25 April 1973,** 6.30 - 8.30 p.m.

Two papers will be presented.

(a) The Solar X-ray Spectrum
(b) Interaction of the Solar Corona and Magnetic field

No admission tickets are needed. Members May introduce guests.

13TH EUROPEAN SPACE SYMPOSIUM
Theme **International Collaboration in Space**

To be held in the Commonwealth Hall, Royal Commonwealth Society, Northumberland Avenue, London, W.C.1 on **25 - 27 June 1973.**

Subject areas are as follows:–

(a) Global Space Projects
(b) European Collaboration in Space Science
(c) European Collaboration in Space Applications
(d) Post-Apollo Collaboration
(e) Round-table discussions

This meeting will be co-sponsored by European space societies in France, Germany, Italy and the UK.

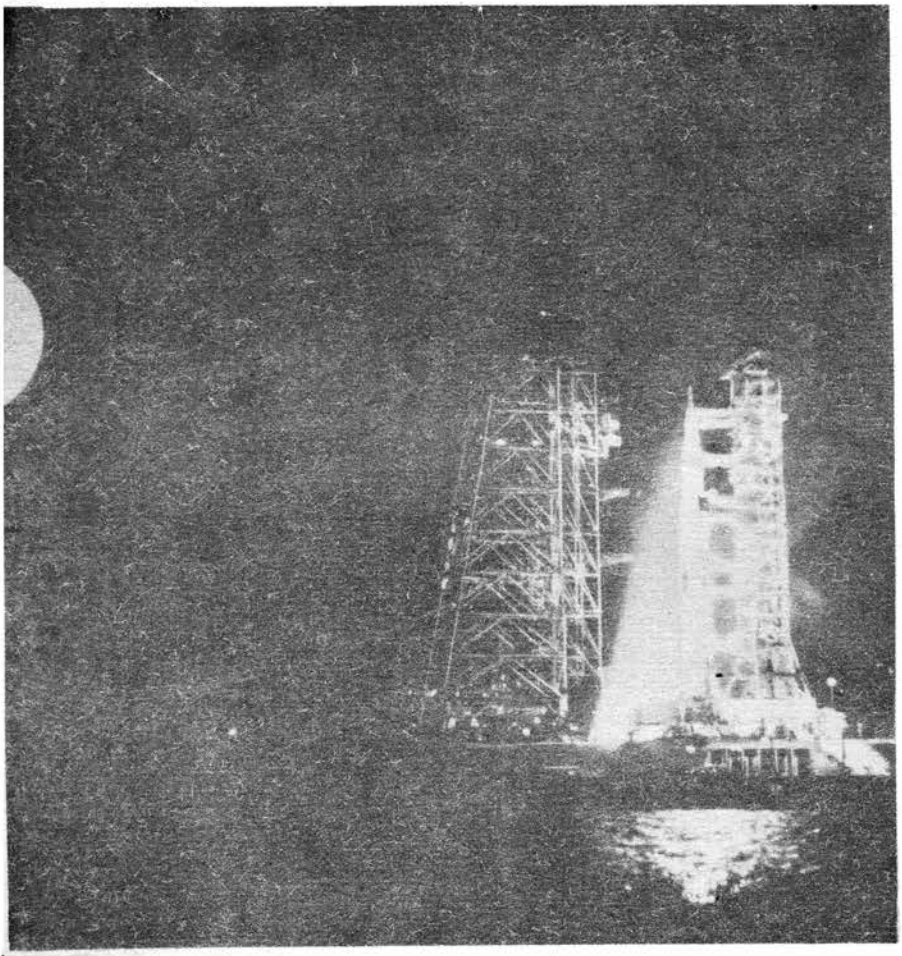
Further details are available from the Executive Secretary.

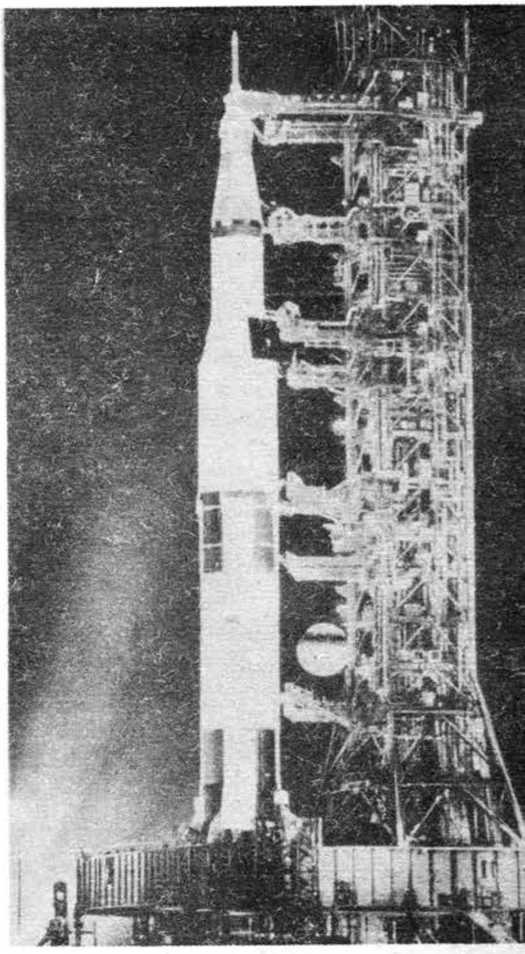
Printed by Unwin Brothers Ltd., at the Gresham Press, Old Woking, and Published by the British Interplanetary Society, 12 Bessborough Gardens, London, SW1V 2JJ.

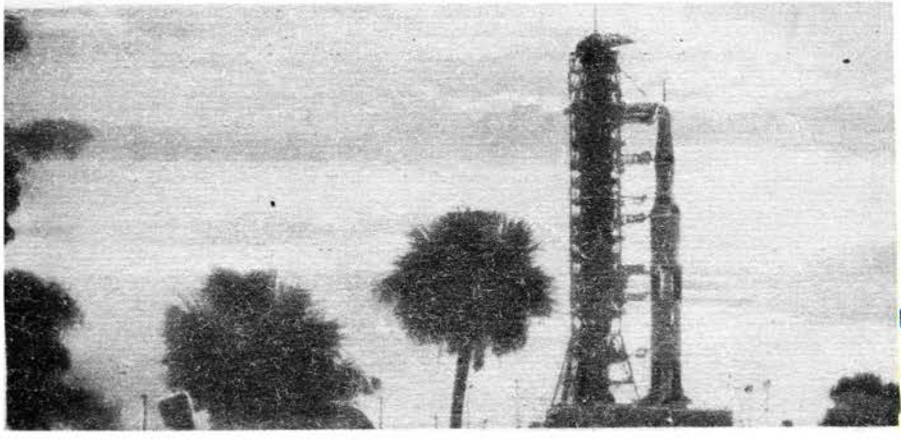
SPACEFLIGHT

88905 КОСМИЧЕСКИЕ ПОЛЕТЫ № Т-2
(спейсфлайт)
По подписке 1973 г.

Volume 15 No. 2 February 1973







Published by The British Interplanetary Society

SPACEFLIGHT

A Publication of The British Interplanetary Society

VOLUME 15 NO 2 FEBRUARY 1973 *Published 16 Jan 1973*

Editor:
Kenneth W. Gatland, FRAS, FBIS

Assistant Editor:
L. J. Carter, ACIS, FBIS

CONTENTS

COVER

THE LAST APPOLLO.
Sunrise at the Kennedy Space Center (top left) before the departure of the last Apollo manned mission to the Moon on 7 December 1972. *Right,* close-up of Apollo 17 on Launch Complex 39A. *Below,* a long-shot of the vehicle framed in sub-tropical vegetation. The spectacular night launching at 00.33 a.m. EST was witnessed by a large party of B.I.S. members who saw the immense torch of Saturn 5's engines light the area as bright as day (see page 42).

All pictures by Jacques Tiziou

MILESTONES

Nov

22 NASA launches 115 kg ESRO 4 satellite by 4-stage Scout at 00.17 GMT into near-polar orbit ranging between 280 and 1,100 km from Earth from Western Test Range, California. Carries 5 scientific experiments to study ionosphere, near magnetosphere and auroral and solar particles; also an infra-red horizon indicator as technology experiment. Prime contractor: Hawker Siddeley Dynamics, with international team of sub-contractors from France, Italy, Denmark, West Germany, Netherlands, Spain and USA.

24 *Tass* announces that a series of carrier rocket launchings will be made between 24 November and 31 December into Central Pacific. Target area of 50 n. miles radius is centred 37° 15'N and 170° 50'E.

Dec

7 Apollo 17 with astronauts Capt. Eugene A. Cernan, Dr. Harrison H. Schmitt and Cmdr. Ronald E. Evans lifts-off at Kennedy Space Center at 00.33 a.m. EST after 2 hr. 40 min. delay. (Scheduled launching at 9.53 p.m. EST 6 December halted 30 seconds before T minus 0 when automatic sequencer failed to command pressurization of S-IVB third-stage oxygen tank). Engine of S-IVB starts Apollo 17 trans-lunar ejection from Earth-orbit at 3.45 a.m. EST, burning for about 6 min. Destination of Cernan and Schmitt in 'Challenger' lunar module is Taurus-Littrow on south-eastern rim of Sea of Serenity. Evans to make independent observations from command ship 'America' in lunar orbit.

7 Michael Heseltine, Minister of Aerospace and Shipping, tells Assembly of Western European Union in Paris that UK Government has authorised him 'to ask my European colleagues if it would not make sense to establish one European space organisation now'. This would have a proper management framework to carry out tasks set it by politicians and could also embrace future national projects.

11 'Challenger' lands at Taurus-Littrow on intended target area at 7.55 p.m. GMT. First EVA of 7 hr. 12 min. by Cernan and Schmitt includes deployment of last ALSEP station and short Moon-drive.

12-13 After sampling rockfall from South Massif mountain during EVA of 7 hr. 37 min, Cernan and Schmitt find orange-red soil which may indicate water vapour in lunar antiquity.

13-14 Third EVA of 7 hr. 15 min. ends with unveiling of plaque on descent stage of 'Challenger' signed by 3 Apollo 17 astronauts and President Nixon, commemorating end of Apollo lunar exploration. President Nixon sends astronauts this message: *'This may be the last time in this century that men will walk on the Moon. But space exploration will continue, the benefits of space exploration will continue, the search for knowledge through the exploration of space will continue, and there will be new dreams to pursue based on what we have learned'.*

14 After record 79 hr. on the Moon at 10.56 p.m.GMT, 'Challenger' lifts Cernan and Schmitt to rendezvous with Evans in orbiting command ship 'America'. After docking crew transfer to Command Module with estimated 249 lb. of Moon samples. LM ascent stage discarded to impact on Moon.

THE LAST APOLLO – 1

By David Baker

'I believe that this nation should commit itself to achieving the goal, before the decade is out, of landing a man on the Moon and returning him safely to the Earth. No single space project in this period will be more impressive to mankind, or more important for the long-range exploration of space, and none will be so difficult or so expensive to accomplish'. These words, spoken by President John F. Kennedy before a joint session of Congress on 25 May 1961, set America on course for the Moon in the aftermath of Sputnik. It was a courageous decision and one that has been fully vindicated by the technical skill and courage displayed by all participants, for in fact not one but four men walked on the Moon in the decade of the 'Sixties. Now 12 men – all Americans – have left their footprints in the lunar dust and a bold new age of scientific exploration is under way. Apollo 17 may end a chapter of space achievement, but it is only a prelude to the story that has yet to unfold. Ceylon's Minister of Housing and Scientific Research, Mr. M. H. D. Jayawardena, put the Apollo triumph into true perspective when a moonrock from the first expedition was placed on public display at the Ceylon National Museum in Colombo: 'This rock', he said, 'remains not only as a monument to human genius and courage, but also as a reminder of what man can yet be........ Future ages will look on the Earth, on which Man was born and struggled for life, as only mankind's cradle, and look back on our day not as the high noon of human civilization, but only as the first dawn'.

Kenneth W. Gatland

Political architect of Project Apollo was the late President John F. Kennedy, seen here during a visit to the Manned Spacecraft Center, Houston, Texas, on 12 September 1962. He stands in front of a full size mockup of an early design of the Apollo lunar module.

National Aeronautics and Space Administration

Introduction

More than 9 months before the anticipated flight of Apollo 17, Astronaut Eugene A. Cernan put words to print and wrote a mandate for artist Robert T. McCall to work with in designing the mission badge. He directed: 'Our desire is that Apollo 17 symbolise not the end of an era, but rather the culmination of the beginning of mankind's greatest achievements in his history – achievements which only have as their bounds the infinity of space and time'.

Yet for a moment we cannot see it in this light. The Apollo Programme has been borne like a banner before the brigade of dissenters that have sought to wrestle from mankind its greatest heritage, the urge to explore new goals. It is symbolic in itself that NASA should choose to smile in the face of sadness, radiate enthusiasm in the arms of restraint, and point a way forward to a new era where others project diffidence.

Eight times Apollo had borne in total 22 men beyond the environs of Earth; 10 had landed on the Moon and 3 had nearly perished in the cold depths of cislunar space. Six had flown in Earth-orbit to prepare the way, and a decade before six had flown a tiny Mercury spacecraft to chart a new ocean in an age before the work of Apollo would gather before it the labours of a quarter-million men and women.

It had cost the lives of 3 dedicated astronauts, presented a bill for $25,000 million, involving a gargantuan engineering effort unmatched by any previous achievement of our civilisation. But it had landed man on the Moon and firmly set his head among the stars.

It would be too much to say that this was merely the last flight to the Moon, or indeed to celebrate the beginning of a new era. It stands alone as the final cornerstone in a magnificent monument to a tenacity of purpose that, against great odds, triumphed in an age of discontent.

Men of Apollo 17

It was on 12 Aug. 1971, shortly after the crew of Apollo 15 had returned triumphant to their native planet, that the National Aeronautics and Space Administration publicly announced the crew of Apollo 17. Within one week they held an impromptu press conference for newsmen at the Manned Spacecraft Center and openly displayed their ebullience at the prospect of manning the last flight to the Moon.

These 3 ambassadors of Earth were drawn from varied backgrounds. Each was a specialist in his own rite, and for the first time a geologist was present among them.

The commander, Astronaut (Captain) Eugene A. Cernan was born on 14 Mar. 1932, in Chicago, Illinois, and graduated from Proviso Township High School to attain a B.Sc. in Electrical Engineering and an M.Sc. in Aeronautical Egineering from Purdue University and the U.S. Naval Postgraduate School.

Selected as an astronaut in Oct. 1963, at the age of 31, Cernan made his first space flight just 32 months later. As pilot to Tom Stafford he was slated for the Earth orbit rendezvous and docking flight of Gemini 9. After delays and the loss of the Agena target vehicle, when it failed to ignite at staging from the Atlas, on 3 June 1966 a make-shift docking module, the ATDA, was sent aloft. Ninety minutes later

Stafford and Cernan were launched into orbit and after several hours achieved rendezvous with the ATDA, only to discover that the shroud protecting the docking collar had jammed in the semi-jettisoned position. Docking was impossible and the mission had to be content with secondary objectives.

In a lengthy EVA Cernan was to make his way to the rear of the docking adapter and position himself within the seat of an AMU (Astronaut Manoeuvring Unit). This device resembled a pilot's couch with arm controls for steering the occupant from place to place. It was the forerunner of a fully autonomous personal life support/manoeuvring unit.

After considerable effort had been expended on attempting to don the device Cernan had to abandon the experiment and return to the spacecraft's crew compartment. Three days after launch the flight was over in a splashdown only 0.4 miles off target.

Before the end of 1966 Cernan was serving as back-up to Edwin Aldrin for the Gemini 12 mission and some 2 years after that was designated back-up to Walter Cunningham on the first manned Apollo flight.

Several months later, on 18 May 1969, Cernan was launched in the Apollo 10 command module with Tom Stafford and John Young on an 8 day rehearsal of the lunar landing mission. From lunar orbit Stafford and Cernan simulated the manoeuvres required of a landing crew and explored the final unknown of the operational envelope. Separated from the command module, the LM descended to the point of PDI and ultimately re-docked after evaluating the propulsion and thermal control systems. By 26 May the flight was over.

Two years later Gene Cernan served as back-up to Alan Shepard as commander of the Apollo 14 mission to Fra Mauro. Before the flight, on 23 Jan. 1971, Cernan was piloting a Bell 47G helicopter along the Banana River south of Patrick AFB, Cape Kennedy,on a practice flight shortly after dawn. Cruising the Indian River area he began a slow descent and, misjudging the altitude, struck the water between a small island and the west shore. The helicopter entered the water and broke up. As a fire fire broke out on the surface Cernan, underwater, struggled to release his straps and swam to the surface through the burning fuel to safety, suffering only singed eyebrows.

Cernan's competence as an astronaut and a professional pilot deserves recognition and his own, hard boiled attitude toward his crew choice is typical of the man. He once said 'They're not a binch of kids out flippin coins and trading candy kisses to see who's got an opportunity to go to the Moon. It's a heck of a lot more serious than that and I think we all look at it with a very professional approach'.

One of the most controversial issues regarding Apollo crew selections concerns the apparent absence of scientist-astronauts in the list. In the 6 manned lunar landing missions attempted before Apollo 17, all the crews were drawn from the pool of professional pilots that make up the bulk of the astronaut corps.

Indeed, for Apollo 17 another pilot-astronaut Joe Engle was originally expected to fly with Cernan to the lunar surface. Engle, now aged 40, had achieved distinction in the X-15 programme and was selected as an astronaut in April 1966. He helped to qualify the Apollo Block II command module before its first flight in late 1968.

However, a decision had been made that at least one scientist astronaut should fly to the Moon and when Apollo 18 and 19 were cancelled in late 1970, Engle was already assigned to the Cernan crew as back-up to Apollo 14. Yet when their duties were done the team was split and Joe Engle had to step aside in favour of a scientist, Dr. Harrison H. Schmitt. In order to provide Schmitt with operational training he was allocated to the back-up team covering Apollo 15 and upon completion of that mission he was named as Lunar Module pilot for Apollo 17.

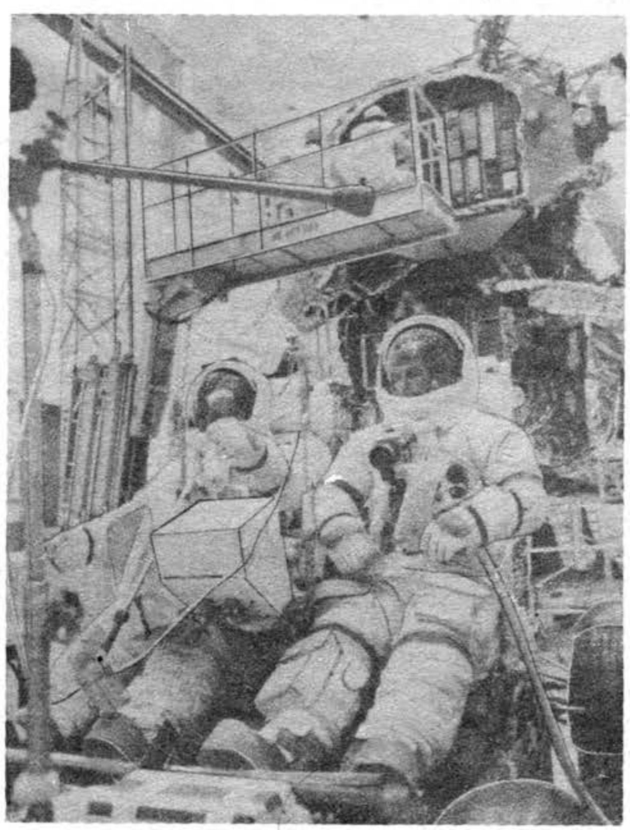
Born 3 July 1935, Schmitt graduated from Western High School in Silver City, receiving a B.Sc. degree from Caltech in 1957 and studying for 2 years at the University of Oslo in Norway. From there he went to work for the Norwegian Geological Survey and, in 1961, he taught geology at Havard with special reference to ore deposits, spending 2 summers in Alaska.

From there he went directly to the US geological Survey's Astrogeology Branch at Flagstaff, Arizona, to assume the position of project chief for lunar field geology analysis specialising in photo and telescopic mapping of the Moon, and assisting NASA astronauts with their geology field trips.

Schmitt was finally selected as an astronaut in June 1965 and spent more than a year learning to fly at Williams Air Force Base, Arizona. He has played a prominent role in teaching astronauts assigned earlier lunar landings and contributed valuable understanding of their own unique problems. Of his fellow crew members Schmitt said: 'You've got to remember that we're going up there as a team and that whatever profess-

Final Apollo team. Astronauts Eugene Cernan (right) and Dr. Harrison Schmitt check out the Lunar Roving Vehicle (LRV) at the Kennedy Space Center. In the background technicians work on the 'Challenger' lunar module.

United States Information Service



ionalism I may have I can translate into the team and whatever Gene and Ron have will be transferred in part to me'.

The third member of the crew, Navy Commander Ronald E. Evans, was born on 10 Nov. 1933. At the time of astronaut selection in April 1966 he was operating combat missions from the Pacific. He holds a B.Sc. in electrical engineering from the University of Kansas and an M.Sc. in aeronautical engineering from the US Naval Postgraduate School.

He was first assigned as a member of the support crew for Apollo 7 and 11 and was back-up command module pilot for Apollo 14.

The Hardware

The command and service modules for Apollo 17 (CSM-114) were essentially similar to the Apollo 15 and 16 vehicles with only superficial changes in the experiment control equipment.

The command module at 12,844 lb was 30 lb heavier than CM-113 (Apollo 16). The service module weighed in at 54,044 lb, 37 lb heavier than SM-113. This gave a total CSM weight of 66,888 lb fully fuelled and ready for launch. Some 40,796 lb of SPS propellent was contained within the 4 service module tanks, about 250 lb more than that carried on Apollo 16. The cryogenic quantities were also up slightly on Apollo 16. More than 1078 lb of LO_2 and LH_2 were carried for fuel cell operation, some 40 lb more than in SM-113.

Lunar Module 12 was about 5 lb heavier than Apollo 16's LM-11 at 36,244 lb. Normal propellent and environmental fluid quantities were carried within the tanks and LM-12 was more closely matched to the LM-11 configuration than was the CSM.

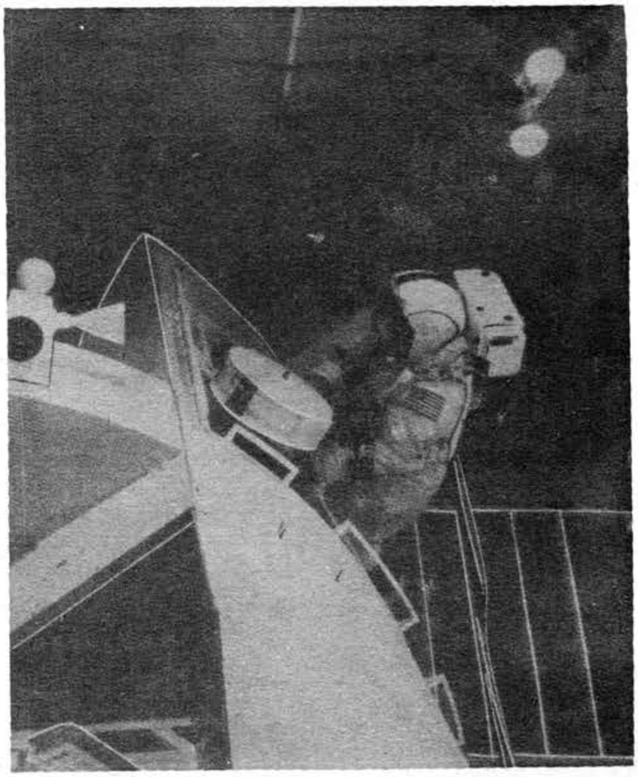
Attached to the LM but operated as an independant item of space hardware the Lunar Roving Vehicle weighed 461 lb when deployed, with more than 1,000 lb added at varying times throughout the EVA traverses.

Launch vehicle for Apollo 17's payload of CSM-114, LM-12 and LRV-3, was Saturn V SA-512, the final three stage flight configuration likely to reach operational status. Launch vehicle 513 is scheduled for a two-stage Skylab launch with SA-514 serving as back-up. In the event that the orbital workshop assembly is launched satisfactorily on 30 Apl. two Saturn V vehicles will remain redundant to the needs of NASA.

On the launch pad the Apollo 17 vehicle weighed 6,530,819 lb, nearly 5,000 lb heavier than Apollo 16 and heavier than any other launch vehicle yet sent spaceward, a record which could stand for the remainder of the century. SA-513 launching Skylab will weigh considerably less than this and at present no plans exist for launching either of the 2 remaining Saturn V's. Only the Shuttle will approach to within two million pounds weight of this value for Apollo 17.

During the ascent phase the Apollo 17 S-1C first stage consumed more propellent than S-1C-11 (Apollo 16) and at centre engine cut off the total stack was already lighter than its predecessors. The second stage configuration, too, was lighter at ignition but less propellent was consumed than with S-11-11 and at engine cut-off the stack weighed more than Apollo 16 at this point. At Earth-orbit insertion the third stage and payload assembly was some 2,000 lb lighter than Apollo 16.

In the boost phase the trajectory was optimised around a lower acceleration during first stage thrusting up to centre engine cut off on the S-II. As an example tower clearance at 10 sec into the flight was achieved at an inertial velocity of 73 ft/sec versus 77 ft/sec for Apollo 16. Orbit was planned



Underwater training. Astronaut Ronald Evans – command module pilot – retrieves a film canister from a submerged mock-up of the Apollo 17 service module, a task he had to perform during EVA on the return flight from the Moon. The water environment gives the astronaut the 'feel' of working in space.
United States Information Service

to be achieved at a lower altitude than Apollo 16 at 567,215 ft.

Consumables have always been a limiting factor on any mission to space. Until the advent of closed-loop environmental and subsystems support equipment in manned spacecraft this must always be the case.

CSM-114, while performing a demanding J-series long-duration mission, retrained a conservative margin in most areas. Service Propulsion System propellent reserves included a 172 lb end-of-mission margin even assuming a major SPS burn to effect weather clearance upon arrival at Earth. Some 378 ft/sec was available if the spacecraft selected the landing area targeted at trans/Earth injection. Nominally, 3% of the propellent load remained at separation from the command module.

Atitude control propellent was retained in abundance. Nearly 50% would remain after a nominal mission.

The cryogenics aboard SM-114 were used for production, in the fuel cells, of electrical power for all spacecraft systems. Under normal conditions 35% of oxygen and 22% hydrogen remained at the end of the mission.

Propulsion systems in the Lunar Module were by necessity more tightly configured on propellent reserves than the CSM. For Apollo 17 LM-12 contained 19,445 lb of useable descent propellent, with 625 lb remaining after a 13 min. 15 sec. descent. The optimum descent trajectory required 12 min. flying time providing a 67 sec. additional hover time over

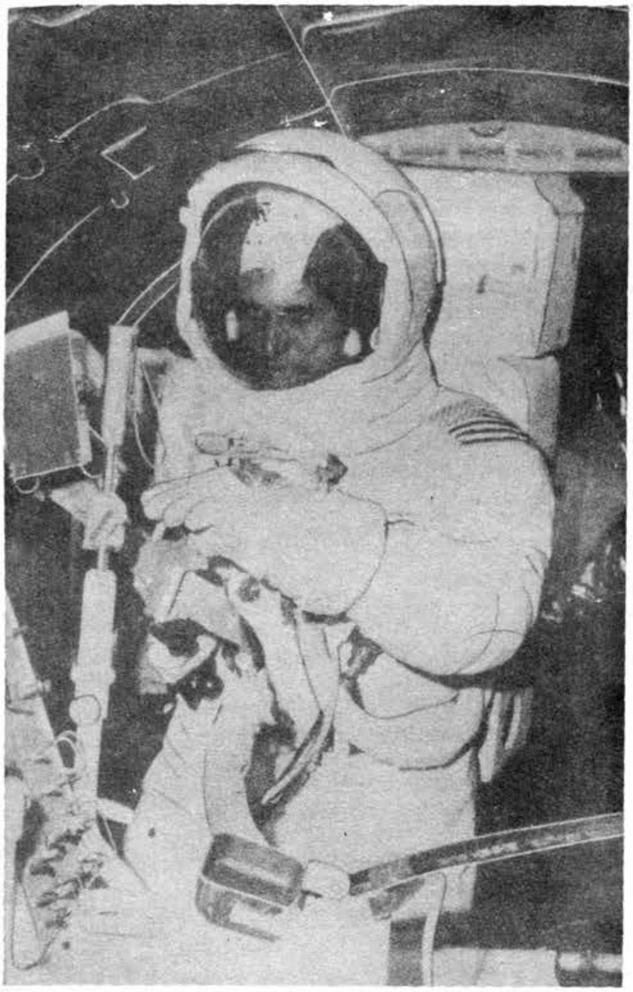
the landing site, or 12 sec. decision-to-abort time.

Ascent propulsion consumption profiles gave a 186 lb margin from the 5,193 lb in the ascent stage at lift-off. This value of 3.5% allowed for engine valve malfunction, out of plane correction, and balanced couple contingencies, assuming a partial RCS component of the TPI delta-V burn provided by the ullage manoeuvre. Atitude control propellent was budgeted to provide a 49% usage of the total available supply, with 17% remaining at lunar surface impact. Electrical power was obtained from both descent and ascent stage supplies. From a total 2,075 amperes available at Earth launch the descent stage had 380 amperes remaining at ascent stage lift-off, and the ascent stage itself had more than 50% remaining at jettison.

Environmental control required 504 lb of water with 419 lb stored in the descent stage, and 98 lb of oxygen with 94 lb stored in the descent stage. Of these totals 15% of descent stage water remained at lunar lift-off, and 62% remained in the ascent stage tanks at jettison. Oxygen was even more conservative. At lift-off more than 48% remained in the descent stage and some 72% was left in the ascent tanks at jettison.

Astronaut-geologist Dr. Harrison Schmitt flew in a KC-135 aircraft into order to achieve semi-weightlessness in a parabolic flight over Florida. Working in a one-sixth gravity environment similar to that on the lunar surface, he practiced deploying scientific equipment.

United States Information Service



It is appropriate to contemplate the reserves that would have been available if the CSM had been stranded in lunar orbit, or the LM on the surface. This was probably the last mission that NASA will launch without a rescue capability for every part of the profile and when lunar exploration is resumed, hopefully about 1985-87, the SNPS (Small Nuclear Propulsion System) that could effect the transport of personnel to lunar orbit will depart with a back-up waiting in the event of a deep space abort.

In the event that the CSM failed to perform its trans-Earth injection burn during Apollo 17 the crew would have faced a depletion of the cryogenic O_2 and H_2 within about 10 days, assuming similar consumption rates. With all electrical power gone the vehicle would be incapable of supporting life but food and LIOH cannisters would last until this point had been reached.

The LM was marginally more flexible. It has two sets of electrical, environmental, and support systems. Descent stage electrical power would last a further 30 hr. if 'power down' was effective within the first hour. The ascent stage could continue to supply power for a further 35 hr. Thus, budgeting for electrical supplies only the LM could provide power for more than 2½ days beyond the nominal lunar lift-off time. Water was the most critical item. Only 35 hr. remained in the descent tanks, with 10 hr. in ascent tanks, limiting spacecraft cooling to the first 2 days of an emergency situation. Sufficient oxygen remained in the descent stage for 10 days with a 10 hr. supply in the ascent stage. Therefore, cooling would be lost less than 48 hr. after the scheduled lift-off time, with battery power depleted 12 hr. later. During the intervening period the crew compartment would become progressively less habitable. Never again will a crew have to face such finality.

The Mission Profile

On almost every lunar landing flight a new technique or innovative application of earlier experience has marked it from its predecessor. For Apollo 17 several portions of the flight envelope were new. TL 1 occurred over the Atlantic for the first time, with the burn phase programmed for a position due west of the Guinea coast, south-west of Mauritania.

The lunar orbit insertion gamma was lower than for any other mission yet flown, helping to produce the 88 hr. transit time, and shifting the semi-major axis of the approach hyperbola further toward the equigravisphere. With perilune placed 10°due west of the landing site versus 16.5°east on earlier missions, the spacecraft was accelerating and descending over the sub-spacecraft landing point Two revolutions later the initial 171 x 5 nm orbit was changed to 15 x 59 nm for its low-perilune parking orbit.

On revolution 12 the two vehicles separated and 1 hr. 27 min. later, around the far side prior to rev 13, the LM performed a second descent orbit insertion manoeuvre to lower perilune to 7.2 nm (56,544 ft some 280 miles uprange of the landing site) on the front side. Six min. prior to this burn the CSM had circularised its orbit to await confirmation of a safe landing. Forty nine minutes later, the LM in its 7.2 x 60 nm orbit swung further out around the eastern limb, breaking out communications with Earth some 3 min. earlier

than if the perilune were at the normal position of 280 nm uprange of the landing site.

This new technique not only provided nearly 15 min. of acquisition time before landing but also placed the spacecraft in a more satisfactory position for landmark tracking. When the LM came around the eastern limb of the Moon the busiest 10 min. began. In that time communications were established, the LM was tracked for updates to its PGNCS and AGS, a state vector was uplinked from Houston, the radius-to-landing-site update was computed, the AGS was loaded for abort and P63 was selected through the DSKY for descent propulsion ignition. At this point the PGNCS was aligned with the AGS, noun 69 RLS updates were fed to the lunar guidance computer and status checks culminated in a 'go' for PDI. Immediately following ignition, downrange, cross-range and radius vectors were fed to the LM from Earth to assist the LGC in optimising the trajectory.

The remainder of the mission conformed to a typical J-series profile with one phase change effected after surface operations were concluded.

The Landing Site

When NASA decided it would cancel Apollo's 18 and 19 in late 1970, only 4 lunar landings remained. Already the Fra Mauro site had cost twice as much money and required the efforts of 6 astronauts to achieve, a landing being made on the second attempt. Three areas thus remained for the sophisticated and elborate hardware of the J-series missions. Apollo 15 went to the Apennines and a rille called Hadley. Apollo 16 would set its landing craft down on the lunar highlands. Apollo 17's site remained unselected.

Controversy followed as scientists debated the rationale for sites as diverse as crater interiors and farside locations. The results obtained by Apollo 15 and its Scientific Instrument Module from orbit emphasised the advantages of constructing a map of the entire Moon showing chemical composition, magnetic anomalies, gravitational field, and detailed tyrographic features.

Consequently Dale Myers instructed the Manned Spacecraft Center to examine the feasibility of placing CSM-114 in lunar polar orbit, there to stay for 9 days and perform a reconnaissance of the western hemisphere before returning to Earth. Energy requirements approached 3,200 ft/sec for a 51,000 lb mass, versus 2,900 ft/sec for a 89,000 lb mass to equatorial orbit. This was well within the capability of the CSM and proposals were issued for a satisfactory payload such as a replica of the ASTP docking module or a Nimbus 4 satellite to be left in lunar orbit for continual surveillance at optimum lighting angles.

In the final analysis, however, the decision was made to utilise all the existing hardware originally scheduled for Apollo 17. A low inclination site would be selected.

Many months were spent in careful deliberation. Several exciting sites had earlier been proposed and the interior of Copernicus, the Slopes of Tycho, the crater Aristarchis, and the rolling undulations of the Marius Hills emerged as candidates. Yet in the end it was a post-flight report by Apollo 15 command module pilot Al Worden that finally clinched the matter. Worden claimed to have seen volcanic cinder cones in an area lying among the Taurus Mountains, south of the crater Littrow, and east of the *Serenitatis* basin. His photographs backed this up and by Feb. 1972 the Site Selection Board had targeted Apollo 17 for the site they called Taurus-Littrow.

Specifically, the landing site lay at 30°44' 58.3", east by 20° 09' 50.5" north and was bordered to north and south by massive slopes, and to east and west by undulating hills. Unlike Apollo 15, the LM for Apollo 17 would be unable to translate further downrange.

Geologically the region is representative of a large portion of the stratigraphic column. The massifs to north and south were formed from the arcuate uplift that built the rim of the *Serenitatis* basin when a minor planetismal ripped out the crustal layers and penetrated the lunar mantle. Indirect evidence indicated the massifs to consist of breccia with variable sources that could include the *Serenitatis, Nectaris, Crisium* and *Imbrium* basins.

If the majority of this massif material were laid out by the *Serenitatis* impact it was reasoned that the early highland crust would lie within inches of the 5 particulate accumulations.

To the south east lay a third massif unit. The LM had to fly over the northern edge of this area during the approach phase of descent. Further east, and trending north, were the Sculptured Hills, a unit characteristic of several areas in the *Mare Serenitatis* and *Mare Crisium.* Visually this feature presented a format of closely spaced hills, well rounded and of undecided origin.

Material believed to have moved downslope from the massifs and sculptured hills formed a layer similar in appearance to the latter and knowledge of its origin could add considerably to a correlation between this and its parent feature. Additional regions of light and dark mantling covered the floor of the landing site and extended to the slopes of the mountain ranges to north, south and east. This material was presumed to be a loose fine-grained composite several feet thick and found in other large basin areas.

Pre-flight thinking on the dark mantle defined this as a fine volcanic ash dust transported from vents and fissures as yet undetected. Overlying this a light mantle extended across the former in scant exposures of thin sheeting thought to be very young material deposited from the massif slopes.

A pronounced east-facing scarp, or fault line, cuts into the north massif some 3 miles west of the landing site, with elevations exceeding 200 ft in certain areas. Photographs of this exposed face make possible visual analysis of the underlying strata, uplifted by the faulting.

Flight Preparations and Launch

More than 2 years before the actual launch date of Apollo 17 the hardware for these vehicles began arriving at the Kennedy Space Center. CSM-114 was in the altitude chamber at the manned spacecraft operations building during the spring of 1972, and was joined by LM-12 in June.

These vehicles were removed from the chambers in July and assembled within and onto the SLA that shrouds the LM and mates with the CSM. They were then transferred to the Vehicle Assembly Building on 24 Aug. for launch vehicle mating and fitment checks. Launch vehicle build-up had begun on 15 May when S-IC-12 was swung onto Mobile Launcher 3. Six weeks later the SA-512 was ready for its payload.

Rollout to Pad A of Launch Complex 39 began on the morning of 28 Aug. and was completed that afternoon. This was the last Saturn/Apollo to leave the Vehicle Assembly Building, sliding through open doors so cavernous they could accept the United Nations HQ. It slowly moved off down the long road to the departure point of 11 of its predecessors. Only 1 vehicle had left from Pad B, which has since been modified for the smaller Saturn IB ready to ferry Skylab crews

to their waiting platform in space.

For 14 weeks and 2 days SA-512 would await its moment in history. First numerous checks and tests had to be carried out. An electrical systems test performed on 11 Oct. was followed by a Flight Readiness Test, held one week later, for 3 days.

The single shift attention directed to SA-512 was in marked contrast to the round-the-clock tempo of early 1969 when Saturn V/Apollos were flying off the pad at almost two-monthly intervals. Gone were the days when engineers sacrificed their coffee breaks to attend to a systems alarm call. Gone too were the times when technicians volunteered to stay beyond their shift and spend hours of unpaid overtime devoted to their own small part of the vehicle, nursed with long hours of painstaking effort.

Present were the few who have seen several hundred thousand of their colleagues rejected with a magnitude of diffidence equal to the clamour that accompanied their recruitment 10 long years before.

Many would wander past this silent behemoth in the weeks preceding launch, some stopping to capture a celluloid image of a page in history, others to gather children around them and move on as though to linger might imbue an addictive aura upon their offspring. Space is still too embarrassing to bequeath willingly.

The final full dress rehearsal, the countdown demonstration test, or CDDT, was initiated on 20 Nov. This simulation was divided into 'wet' and 'dry' portions, with the crew participating in the unfuelled, or later test. The 'wet' CDDT which lasted 1 day rehearsed the fuelling of all 3 stages.

The pre-count preparation clock was started at 8.30 a.m. EST on Thursday 30 Nov. continuing on through to the terminal countdown at 7.00 a.m. EST on 5 Dec. Throughout this long procedure numerous items were replaced but all were minor in nature and the final few hours ticked away uneventfully.

Several forces had combined to threaten the launch. Technical writers from a prominent aerospace company scheduled a pay dispute for the final days before lift-off. Exorbitant settlements of 45% were ordered by NASA to ensure a smooth countdown. The weather took a hand in the proceedings and doubts existed right up to launch day that the last manned Saturn V would actually get off the ground on time.

The time appointed for launch, 9.53 p.m. local time on the evening of 6 Dec.,opened a 3 hr 38 min opportunity that, if passed, would necessitate a 24 hr recycle.

Several hundred thousand people gathered along the roads, on the beaches, at the viewing areas, took boats to water and light aircraft to the skies, bearing witness to the fiery departure of 3 men on a mammoth vehicle the like of which the world will never see again.

Every man and woman who watched with mounting excitement as treble digits slipped to double figures and the countdown moved ever nearer that magic 'zero', held his own thoughts uppermost. Not to just a few did the memory of previous launches slip into mind. The unbelievable smothness of Apollo 4, the near explosion of Apollo 6, the magnificent pride of Apollo 11 as it lit a torch to the Moon, lightning strikes to Apollo 12. Each launch recalls unique events. Each one reprieves lost moments when an eye blinked, a head turned, or the light became just too bright to gaze upward, with promise of another look the next time round. Not so this time!

The air was warm, a pleasant 75°F but not all the sky was stars as the final minute was reached. Of all the promised science and all the technology this moment alone had to be pure emotion. The last great cislunar liner was slipping its berth. Enhanced by the intensive light from 1,580 kw the silky wisps of boiling oxygen streamed from vent ports and unchilled surfaces of the launch vehicle.

The monotone of Chuck Hollinshead's voice was unpreturbed when, at T-30 sec, the count was abruptly brought to a halt and the launch event sequencer pulled the communication line. For the first time in the history of the Saturn V, a countdown had been terminated just seconds from lift-off. The moment was full of suspense and anticipation. Several minutes went by while programme interrogation sought a reason for the shut-down. Almost immediately the count was recycled to the T-22 min mark for a hold at that point.

Rapidly the story was put together. Pressurisation of the S-IVB stage is effected by pumping in cryogenic helium at -340°F for a cavity pressure of 38-41 psia. This is controlled by the terminal event sequencer and required manual intervention when a malfunction in the delivery control unit failed to pump up pressure in the tanks. The terminal sequencers, failing to comprehend the override that was satisfactorily pressurising the tanks, determined that an off-normal sequence was underway and shut down the electrical feed to the nuclear clocks, effectively cutting off further moves in the countdown and locking all manual systems.

A compromise was quickly determined and before the hour was out the Marshall Space Flight Center was running the remodelled instructions on validity tests.

Finally, at 25 minutes past midnight local time, the countdown was resumed from the T-8 minute mark. For the second time the terminal event sequencer moved the countdown near to the point of ignition.

When it came the probing fingers of the searchlights were suddenly blotted out by a blinding splash of fire that rapidly turned to gold as the 5 massive engines in the first stage gulped 13 tons of propellent each second. Then the big bird that was reluctant to leave Earth only hours before lifted slowly and majestically into the black of night.

It is believed that a star reaching the end of its life burst forth in the most magnificent display of power and beauty ever conceived. Of such an impact was the launch of Saturn V SA-512 as with agonisingly slowness the giant vehicle rumbled spaceward. The blinding fury of its ascent eclipsed any previous launch if only for its magnificence. This was the last time a human being would ride such a titanic creation.

All the way to orbit the events cycled off with precision, insertion coming only 2 seconds early. Twice Apollo 17 circled the Earth and finally, on the third pass over the Atlantic, the S-IVB's single J-2 engine was re-ignited for 5 min 52 sec to boost the assembly into a trans-lunar trajectory. With an added component of velocity the 24 hr 40 min delay at launch would be made up during the translunar coast. Apollo 17 was well and truly on its way.

To be continued.]

SPACE EXPORT

Nose shrouds designed for use on the abandoned British Black Arrow satellite launcher will be used on the improved French Diament B-P4 launcher. Three sets of suitably modified shrouds have been ordered from British Hovercraft Corporation.

VENUS: HOW MUCH DO WE KNOW?*

By Michael Marov, B.Sc.,(Phys.-Math.)

Introduction

I well remember a picture in a book about the Universe, published in the middle of the last century, in which the planets of the Solar System were linked by a bridge of lacy design. At that period the link was a product of the artist's fancy yet probably reflected the idea of a common origin of the Solar System. In our time largely through the successes of space rocket engineering, we are witnessing efforts aimed at making such bridges a reality. Space vehicles which have reached the Moon, Venus and Mars have brought back such a wealth of information, that it enables us not only to understand better the peculiarities of these bodies as they are today but, in the final analysis, to come closer to the understanding of the origin and evolution of our own planet and the entire Solar System.

Physical and Chemical Characteristics

Venus is the nearest planet to the Earth and the brightest celestial body after the Sun and the Moon. It closely resembles the Earth in mass, size and the amount of solar energy absorbed. The Venerean atmosphere was discovered by Michael Lomonosov, the great Russian scientist, in 1761. However, until recently, there was wide disagreement over such basic data as the atmosphere and the composition, temperature and pressure at the planet's surface, It has taken more than 200 years to get a clearer picture of the physical and chemical structure of the Venerean atmosphere and its properties.

The data transmitted by the space probes have served as the basis for an adequate interpretation of the studies of Venus using ground-based optical and radio equipment. In particular, it was possible for the first time to get more precise data about the atmosphere. At the same time, progress with radar techniques has reliably established the planet's rotation characteristics and yielded the first data on its shape and surface profile which has altitude fluctuations of several kilometres.

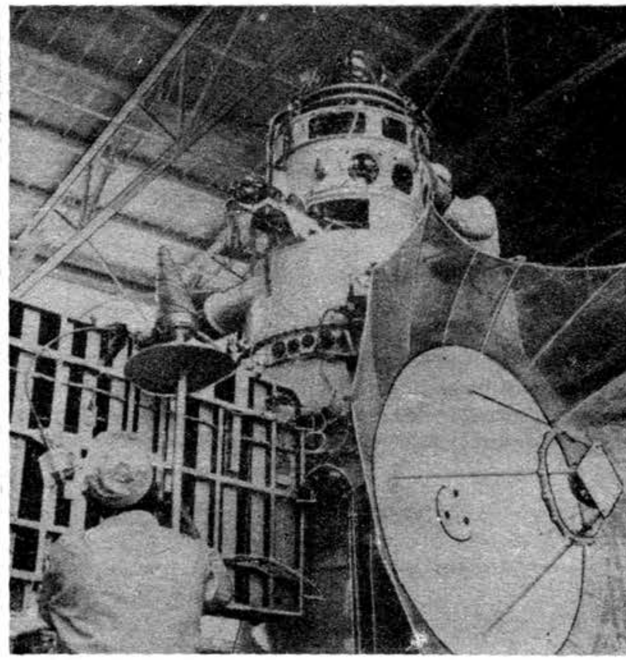
It turned out that unlike other planets of the Solar System Venus rotates from the East to the West, completing one revolution in 243 terrestrial days. It means that during one Venerean year (about 225 terrestrial days) the Sun rises and sets twice on the planet while the Venerean day lasts 117 times longer than a day on Earth.

There is a seeming discrepancy between these figures. The overall picture would be easier to understand if we assumed that Venus rotated eastward, like the Earth. Then it would have its one side permanently facing the Sun so that an observer on the Sun would always fail to see the other side, as with ourselves in the case of the far side of the Moon. However, because the rotation is retrograde, both Venerean hemispheres get exposed to the Sun twice a year and an observer on Venus would see the Sun rise in the West and set in the East; at the equator he would observe twice a year something in the nature of a 'polar night' and a 'polar day' lasting nearly two earthly months.

The rotational axis of Venus is almost perpendicular to the ecliptic and, consequently, there are no changes of seasons on the planet.

Soviet Space Probes

During the past few years Soviet scientists have been carrying out a regular space programme of Venerean research. The historic flight of the Venera 4 automatic interplanetary station in October 1967 made it possible to understand something of the conditions we could expect to find on the planet, while the flights of Venera 5 and Venera 6 in May 1969 supplied more reliable data on the characteristics of the planet's atmosphere, which are essential for landing on its surface. This exceedingly sophisticated task was successfully fulfilled by Venera 7 which in December 1970 transmitted information from the planet's surface.



Venera 8 spacecraft, launch weight 1,180 kg. It soft-landed a 495 kg instrument capsule on Venus on 22 July 1972 after a flight lasting 117 days, see *Spaceflight*, January 1973, p.23.

Novosti Press Agency

The unique data, obtained by the 'Venus' stations and the measurements made by the US spacecraft Mariner 5 which flew past the planet in 1967, led to fundamental scientific conclusions. It appeared that the Venerean atmosphere is almost entirely (no less than 95%) composed of carbon dioxide, whereas the carbon dioxide content of the terrestrial atmosphere (mainly nitrogen and oxygen) does not exceed 0.03%. The amount of water vapour below the clouds is less than 1%. The Venerean atmosphere may have a few per cent of nitrogen and neutral gases, but oxygen is practically non-existent. Studies of the infrared emission spectra of Venus using Earth-based telescopes have shown the presence in the cloudy atmosphere of carbon monoxide and even such components as muriatic and hydrofluoric acids in very small quantities (their content being several ten-millionths parts of that of carbon dioxide).

The climatic conditions of Venus are most unusual. The mean temperature at the surface is about 500°C. which is approximately 30 times that on the Earth, while the atmospheric pressure is, on the average, 100 times higher than on the Earth's surface. Temperature fluctuations in

**Supplied by the Novosti Press Agency.*

the Venerean atmosphere follow nearly the same pattern as in the lower layers of the terrestrial atmosphere and, consequently, one may assume a vertical mixing of gases.

Thermal Distribution

It is possible to conceive of several patterns of heat transfer in the atmosphere of Venus which may explain, in principle, its peculiar thermal characteristics.

Calculation of the radiant energy transfer in the atmosphere leads one to believe that high temperatures at the surface of Venus are apparently produced by the 'green-house' effect. The physical explanation of this is quite simple. Visible sunlight, partly absorbed by the atmosphere and the clouds, reaches and heats the planet's surface. The heated surface then emits infrared rays of longer wave lengths which are impeded by the thick Venerean atmosphere. A similar effect, considerably less pronounced, is also manifest in the terrestrial atmosphere. However, the part played by the atmosphere of Venus in producing this effect is much greater than on Earth. Calculations show that, if only a small part of the solar radiation reaches the surface, carbon dioxide containing little admixed water vapour (also dectected in the atmosphere by the Venus stations) would have a marked shielding effect on the 'back heat' radiation. As temperatures and pressures rise, the shielding effect increases.

Present-day conditions on the planet evidently stem from a gradual self-heating and have reached a certain equilibrium. The latter may be true not only of temperature but also of the geochemical conditions which correspond to the measurements obtained of carbon dioxide content and atmospheric pressure. Unlike the Earth with its moderate temperature, which has approximately the same amount of carbon dioxide as Venus does in the sedimentary rock carbonates (largely due to the action of living organisms), the carbon dioxide on hotter Venus has risen from the lithosphere into the atmosphere thereby producing a high-pressure gaseous envelope.

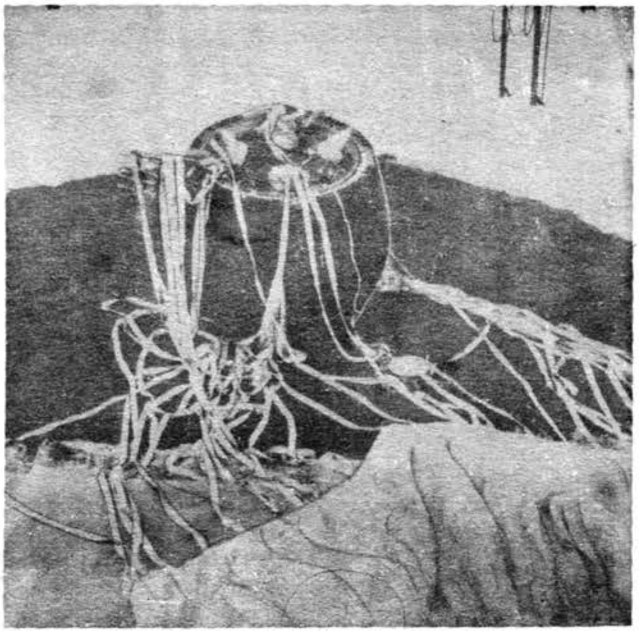
Another possible mechanism of heat transfer – the deep circulation pattern – proceeds from the assumption that solar rays do not reach the surface but instead are completely impeded by the atmosphere and the clouds. In this case the heating of the lower atmosphere may be brought about at the expense of an adiabatic compression of gas. Measurements made by the Venera probes have established a nearly adiabatic vertical temperature profile down to the planet's surface. However, the adiabatic pattern of temperature accompanying convectional gas mixing applies equally to the characteristics expected of the green-house theory. Before we can choose between the two theories, it is essential to know more about sunlight penetration of the visible layer of the clouds. One, of course, cannot dismiss the possibility that Venus's internal heat may play a definite role in the planet's thermal regime.

Atmospheric circulation would play an important part in either of these theories. One may assume that a large-scale transfer of hot and dense gas in the meridional direction brings about heat transfer to the polar regions. The polar temperature, as has been shown by recent radio-astronomical measurements, hardly differs from that of the equatorial region, due to a huge thermal absorbtion of the Venerean atmosphere and the heat it retains, it fails to cool off during the Venerean night (about 60 terrestrial days). It is estimated that temperature fluctuations between night and day at the surface are less than 1°.

If one proceeds from a most probable assumption that the clouds and the dense atmosphere cause a considerable diminution of sunlight,then evidently, the intensity of illumination at the surface of Venus is not too high. It most probably corresponds to terrestrial twilight in over-cast weather. The visibility is also low, as considerable light-scattering caused by molecules of the dense gas is bound to produce fog-like conditions. However, should visibility in the Venerean atmosphere permit, one would be able to observe most astonishing optical effects on the planet's surface caused by a considerable refraction of light in the atmosphere. The horizon would seem raised in all directions, so that the observer would have the illusion of standing inside a huge bowl.

Capsule of the Venera 8 test programme after parachuting on to Soviet soil.

Novosti Press Agency



Nature of the Clouds

A most interesting problem is one involving the nature of clouds on Venus. It is the reflection of solar radiation from the top cloud layer that makes Venus so bright a star in the Earth's sky. The problem of Venerean clouds is complex. and so far we have merely been able to theorize about their size, structure and composition.

The most attractive hypothesis of water-and-ice clouds, resembling those on Earth, is not without certain flaws. For example, unlike the Earth, where clouds seldom rise higher than 10-12 km, similar clouds on Venus would occur from up to 60 km while their depths should reach over 10 km (judging from the measurements of the concentration of water vapour).

Alternatively, there may be large amounts of dust in the atmosphere which allow us to see only the upper layer of a permanent dust cloud. Again Venus may have a laminated cloud structure. The latter could be a unique property of the planet for the surface temperature is higher than the

boiling and fusing temperatures of a whole range of elements and compounds which exist in our natural conditions in a solid state. For example, the atmosphere of Venus may have taken up, apart from the water, also sulphur, bromine, iodine and mercury, while on the surface there might be alkaline metals, lead and tin in a fluid state. However, as temperature falls off with altitude, the vapours of admixtures in the atmosphere would condense at different levels (as is the case with water vapour as temperature drops). One, therefore, should not exclude the possibility of a most peculiar laminated cloud structure on Venus having an unconventional chemical composition of condensates in various layers.

The ultraviolet ground observations show some differences of contrast in the structure of Venerean clouds which are otherwise indistinguishable in the visible part of the spectrum. It has also been observed that the movement of these contrasts, known as 'ultraviolet clouds', along the planet's disk occurs about 60 times as fast as the rotation of the planet itself. On the Earth, the faster rotation of the atmosphere (by no more than 1.2 - 1.4 times) is observed only at very great heights of 150-400 km. The nature of this phenomenon is still not entirely clear. On Venus, it is most probably related to the peculiar features of heat transfer and the planetary circulation at the level of the cloud layer.

Origin of the Planets

The hypothesis of a common origin of the solar planets involving a gigantic protoplanetary gas-and-dust nebula, make one look for similar characteristics among the various planets. Studies made during the past decade have shown conclusively that the Earth, Mars, Venus and Mercury greatly differ from one another. These distinctions may, to some extent, be linked with different stages of planetary evolution. We are beginning to understand something of the way in which the Earth has developed over the course of thousands of millions of years when conditions were very different.

How a particular planet evolves depends on a variety of conditions, above all, its geometric and mechanical properties,its distance from the Sun, internal changes, and the fragmentation of the rock. These processes are accompanied by the formation and evolution of the planetary atmosphere which, therefore, contains a major clue that a definite stage of evolution has been reached. Consequently, study of the atmosphere and its peculiarities makes it possible to draw conclusions concerning the entire planet.

High temperature and pressure, low water content and nearly non-existent oxygen – all these features of the Venerean atmosphere are correlated and mutually dependent. More particularly, a temperature rise results in the atmosphere taking up a greater amount of water followed by carbon dioxide as a result of precipitation of water vapour, which in turn contributes to a further rise in temperature on account of the green-house effect. Therefore, conventional form of biosphere cannot exist at high temperatures, while the absence of the biosphere virtually nullifies the possibility of major quantities of free oxygen in the atmosphere.

One of the most important problems facing scientists at present is one involving a very small quantity of water on Venus. Barring the improbable supposition that water had not been raised from the interior part of the planet by volcanic activity (as was the case with the Earth where it has concentrated mainly in the oceans), then it must be ascertained why water content in the Venerean atmosphere is at least a thousand times lower than on the Earth.

One possible explanation proceeds from the assumption that the temperature of the coldest part of the upper atmosphere of Venus (the mesopause) is 20-30° higher, while sufficiently hard ultraviolet radiation can penetrate deeper than on the Earth. This would result in a more vigorous break-down (photodissociation) of water into oxygen and hydrogen, and a ready dissipation of lighter hydrogen from the atmosphere into space. The oxygen, in its turn, would become fixed into the hard substance of the planet's surface.

The hydrogen halo of Venus was discovered by measurements made by the space probes. However, the evidence is inadequate as the Earth, too, has a hydrogen halo. To be able to draw more positive conclusions, it would be interesting to establish among other things, the hydrogen-deuterium ratio in the upper layers of the Venerean atmosphere.

The few available data on the upper atmosphere of Venus point to a number of curious peculiarities. There is, for instance, reason to suppose that the predominance of carbon dioxide is maintained up to nearly 200-350 km from existing knowledge of the efficiency of the photodissociation processes by solar radiation. This leads one to expect the predominance of oxygen. But there is an insignificant quantity of oxygen. Measurements made by Venera 4 and Mariner 5 have shown the magnetic field of Venus to be over 3,000 times weaker than that of the Earth. Consequently there is no 'magnetic shield' on a par with the magnetosphere of the Earth. This makes for a peculiar correlation of the planet's atmosphere with the oncoming plasma of the solar wind.

The problems discussed above are by no means exhaustive. Indeed, despite huge advances made in the study of the planet, it still lives up to its name as the planet of mysteries.

The thickness of the gas envelope, the peculiar thermal regime, the unconventional rotation of the planet – these and other characteristics set Venus apart from the other solar planets. What caused these unusual conditions? Is the atmosphere of Venus primary, i.e. typical of a young planet, or have these conditions emerged later as a result of irreversible geochemical processes determined by the proximity of Venus to the Sun? These questions demand close attention and further comprehensive study.

KOROLYOV MUSEUM

A memorial museum of Academician Sergei Korolyov (1906-66), designer of Soviet spaceships, is to be opened in Moscow in the house where he spent the last years of his life. The house is situated on a street named after Korolyov in north Moscow, not far from the Cosmos obelisk.

MAN'S PSYCHIC POTENTIAL

Captain Edgar D. Mitchell, the sixth man to walk on the Moon, has formed a private company to investigate the psychic potential of man. Mitchell, who conducted the first extrasensory perception (ESP) experiment from space as a private venture during the Apollo 14 mission to the Moon (*Spaceflight* Jan. 1972 pp. 20-21), retired from NASA and the US Navy last October. The new company is called Edgar D. Mitchell and Associates.

SURVIVAL OF MICRO–ORGANISMS ON THE MOON

By Dr. P. M. Molton*

There has been much disagreement in the scientific literature about how long and under what conditions terrestrial life could survive exposure to vacuum. Recently, there was a unique opportunity to obtain factual data on the subject, with the return of Apollo 12, bearing pieces of the Surveyor 3 spacecraft. On 20 November 1969, the entire TV camera and other selected components were removed from Surveyor on the Moon, where they had been since 20 April 1967. They were sealed and returned to Earth, stored in the Lunar Receiving Laboratory for the quarantine period, and then disassembled and examined.

Pre-launch sterilization of spacecraft is only a partial affair, since sterilization conditions are chosen to give an acceptable trade-off between micro-organism killing and the chance of disabling components by the heat and chemicals used. Consequently, all spacecraft contain a small number of viable micro-organisms at launch.

It was not anticipated that any part of Surveyor 3 would be returned to Earth, and so there was no before launch examination of back-up components to determine their degree and nature of contamination by micro-organisms. This is unfortunate, since there could be no examination of a 'before-and-after' nature. However, backup cameras were available, having been stored since 1967. One was used for testing the techniques, and another was used in parallel with the one returned from the Moon.

The cameras were placed within an iso-propanol washed sterile cabinet, fitted with a laminar-flow sterile air supply. This ensured that no contamination was possible from organisms drifting into the cabinet. The operators wore sterile caps, face-masks and gloves, and all other possible precautions were taken against accidental contamination.

The camera itself contained no lunar material, showing it to have remained leakproof.

A number of cotton swabs were taken from inside the cameras, and inoculated into trypticase soy broth (TSB, for growth of aerobic organisms), into thioglycollate broth (THIO, for anaerobic organisms), and into yeast malt broth containing streptomycin and penicillin (YMB, for growth of fungi) [1]. The sites tested are listed in the Table 1.

Table 1. Microbial sampling sites of the Surveyor 3 and TAT-1 TV cameras. Sampling sites 1 and 2 are camera samples pertaining to the Surveyor 3 TV camera only. The TAT-1 camera had no collar cables; consequently, no sample of site 1 was taken. Site 2 included all 3 exterior metal cable connector surfaces.

Sampling site	Tube number TSB	THIO	YMB
1. Metal surface under front half of collar	1	11	21
2. Nylon ties, Teflon wrapping, cable connector surface	2	12	22
3. Surface area on support studs	3	13	23
4. Surface area on electronic conversion unit	4	14	24
5. Circuit board support-plate edges and screw studs	5	15	25
6. Surface area of all 3 cable connectors inside camera	6	16	26
7. Nylon ties and cable wrappings	7	17	27
8. Debris in bottom of shroud	8	18	28
9. Large area on inside of shroud	9	19	29
10. Top surface of exposed circuit boards	10	20	30
11. Foam samples from between circuit boards	31	32	33

Standard precautions were taken against contamination of the culture tubes. The original culture was diluted by 10 and 100 with fresh broth, and samples of each dilution were plated on to 3 agar-nutrient plates to permit colony development. This is so that the number of micro-organisms present in the original sample could be determined. Failure to show consistent results, such as, for example, growth in a ten-fold dilution tube without growth in the undiluted sample, or differing number of colonies on the 3 plates inoculated from the same sample tube, was taken as evidence of contamination, and the result was ignored.

The only positive result obtained was from 32, which showed growth in 3-4 days incubation in undiluted THIO medium, from a 1 mm^3 piece of foam from the Surveyor 3 camera. The organism was identified as *Streptococcus mitis*.

The backup camera contained more organisms, identified as a *Bacillus* species, an *Aureobasidium* species, and *Aspergillus pulvinis*.

Since only 1 tube showed growth, from a single sample, possibly from only a single microbial cell, the result is in question. No growth was obtained from other parts of the lunar-retrieved camera, or from electrical cabling similarly examined [2]. The bodies of the astronauts were host to *S. mitis*, together with a number of other organisms. Despite the careful approach, contamination by the investigators is a possibility, which is why the result has been met with scepticism.

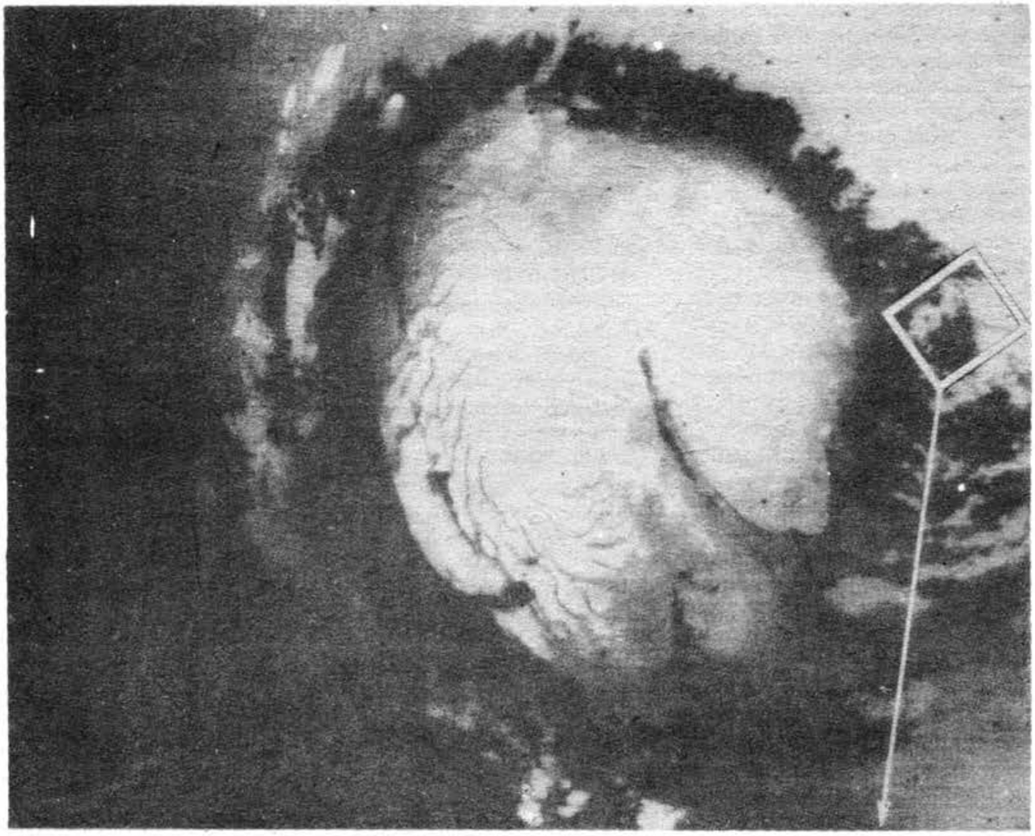
If we believe it, a terrestrial organism remained viable after 2½ years on the Moon, in vacuum, alternately heated and frozen, and subjected to solar radiation. Perhaps future missions to the Moon will be able to confirm or deny this report.

REFERENCES

1. F. J. Mitchell and W. L. Ellis, 'Surveyor III: Bacterium isolated from lunar-retrieved TV camera', *Proc. 2nd Lunar Sci. Conf.*, Vol. 3, 2721-2733 (1971), M.I.T.Press.
2. M. D. Knittel, M. S. Favero and R. H. Green, 'Microbiological sampling of returned Surveyor III electrical cabling', *Proc. 2nd Lunar Sci. Conf.*, Vol. 3, 2715-2719 (1971), M.I.T. Press.

**Laboratory of Chemical Evolution, Department of Chemistry, University of Maryland, College Park, Md.20742, USA.*

VISTAS OF MARS



Mariner 9 sent its last picture on 27 October 1972. Photography began on 10 November 1971, during the final approach to Mars and during nearly a year of active life, 7,329 pictures were taken covering the entire surface of the planet. This remarkable achievement – together with masses of scientific data about the environment of Mars which will take years to analyse in detail – stands as a landmark in planetary exploration. Mariner 9 took this picture of the north pole of Mars on 12 October 1972 as it made its 668th revolution. It shows the polar cap at its minimum extent, about 1,000 km (620 miles) across. Curved patterns in the interior of the frost cover are formed on outward facing slopes receiving more direct sunlight than the flat areas and defrosting earlier. The various shades of grey correspond to surfaces of very bright carbon dioxide and, perhaps, water ice, and bright and dark rock debris. The spiral pattern and the eroded channel running from the cap centre toward lower right are characteristic of the layer sedimentary complex localized in the central regions of both poles. A dark collar of roughly textured terrain surrounds the central polar deposits. The owlish countenance of Mars (below) is a high-resolution picture of the position marked taken the same day. Covering an area 150 by 200 km (90 x 125 miles) and located 74°N latitude, 14°W longitude, the photo shows a complex collection of albedos and textures typifying the kinds of geological evolution in Mars' north polar region. The dark patches on the floors of the two circular craters are caused by variations in the character of the materials and not simply by lighting effects.

Jet Propulsion Laboratory

EARTH RESOURCES TECHNOLOGY SATELLITE

By David Dooling, Jr.

Introduction

Since he first climbed a tree man has realized that a better view can be had of his domain from the 'bird's eye view'. Now, following the launch of Earth Resources Technology Satellite A (ERTS-A), he is getting what one engineer referred to as the 'God's eye view'.

For many years scientists and engineers have been aware of the advantages of orbital photography over even high altitude aircraft photography. A satellite, once in orbit, does not have to land every few hours. It can cover in one photograph a region that aircraft must do in mosaic (thereby introducing distortion). By selection of the proper orbit the satellite can, in a sense, be everywhere and offers repeated coverage regardless of flying conditions. Also, over the past few years, there has been an increasing awareness of the potential of resources sensing from high altitude.

After several years of manned and unmanned spacecraft photography and a few years of aircraft remote sensing photography the National Aeronautics and Space Administration began development of a satellite wholly dedicated to remote sensing. General Electric was selected to build ERTS A & B, the only two authorized so far. (A camera aboard the GE Mark II re-entry vehicle took the first photo of the Earth from space in 1959). The ERTS programme consists of two major parts. The first is the satellite. But the satellite is no more the entire programme than a man's eye is his entire brain. Thus, the second part of the programme is the processing centre for ERTS photos.

Spacecraft Design

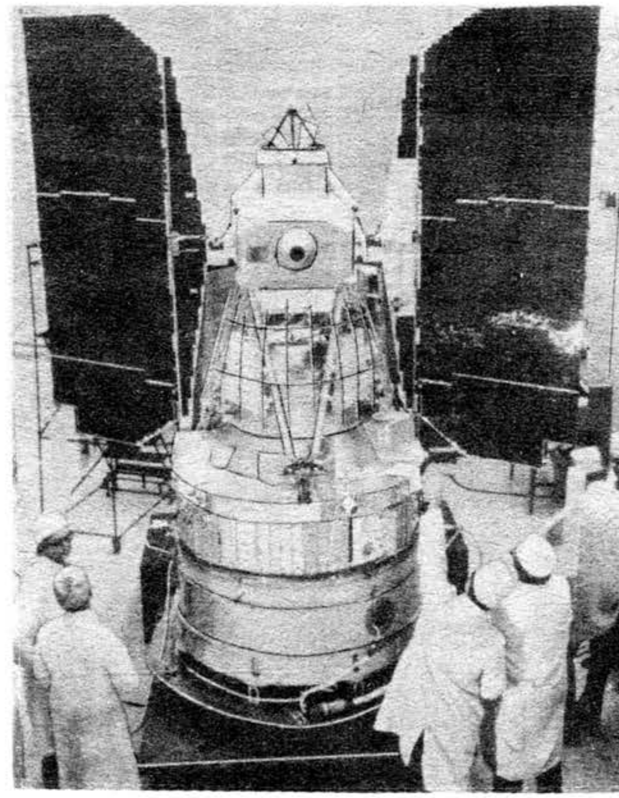
ERTS closely resembles GE's Nimbus weather satellite for good reasons – Nimbus was the springboard for the ERTS design and some of the ERTS hardware came, with appropriate modifications, from Nimbus. Looking much like a flying windmill ERTS has a disc-like main bus housing sensors and communications equipment. Struts on top of the main bus support the attitude control subsystem and the two solar panels.

Those two panels provide up to 512 watts of primary spacecraft power. The panels rotate to face the Sun as ERTS orbits the Earth. Since the ERTS orbit is designed to pass the equator at 0930 local time the panels are canted slightly to keep them perpendicular to the Sun. Secondary power, used during launch peak loads and nightside passes, is provided by 23 rechargeable nickel cadmium batteries.

Since many of the ERTS experiments require that the satellite use exactly the same ground track the spacecraft cannot be allowed to drift more than 10 miles from its original orbit. Two 1 lb. hydrazine decomposition thrusters onboard provide 45-fps of delta-v for this purpose.

Data from ERTS, either real time or taped, is first sent through a video switching matrix which integrates signals from the 3 cameras, one scanner, the data collection system and spacecraft telemetry and sends it to either of two frequency modulators. From there the data pass through a hybrid switching and summing network and then to either of two travelling wave tube power amplifiers. In the event that one TWT should fail the other can handle both frequency modulators on a time sharing basis or the hybrid summing network can degrade the total data package so both modulators can transmit. ERTS transmits on two 20 MHz wide bands centered on 2229.5 MHz and 2265.5 MHz.

For periods when ERTS is out of sight of ground stations there are two wide band video tape recorders (WBVTR) for data storage. Each WBVTR has 2000 ft. of 2 in. wide magnetic tape. To maximize data density and reduce distortions caused by tape slippage over a conventional head a special spinning head is used (Conventional heads have up to 32 channels side by side across the width of the tape. Slippage across the width can cause distortion of data). Four recording heads are located at 90° intervals on a rotating disc. The 2 in. width of the tape wraps 110° around the head. One line recorded across the tape's width corresponds to one line on the 3 TV cameras or the scanner. Part of the line on the tape is devoted to telemetry and the data collection system. Although the tape moves at only 12 in/sec. the spinning tape head gives and effective speed of 2000 in/sec.



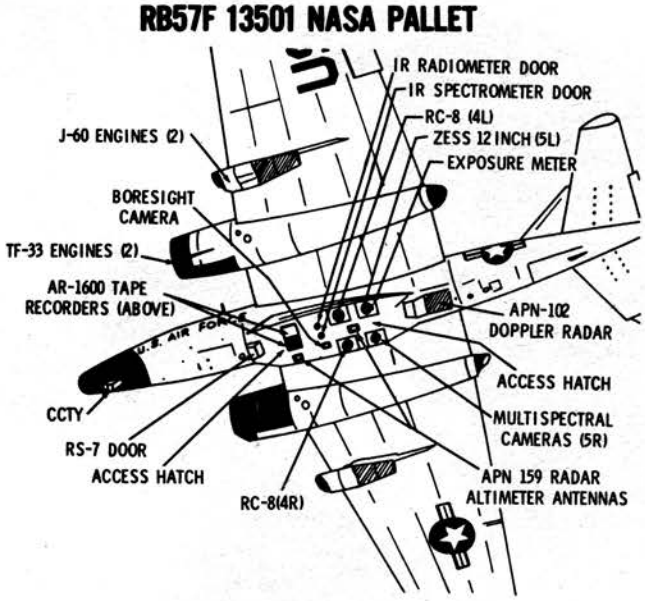
Earth Resources Technology Satellite (ERTS-1) launched into polar orbit from the Western Test Range on 23 July 1972.

United States Information Service

ERTS Payload

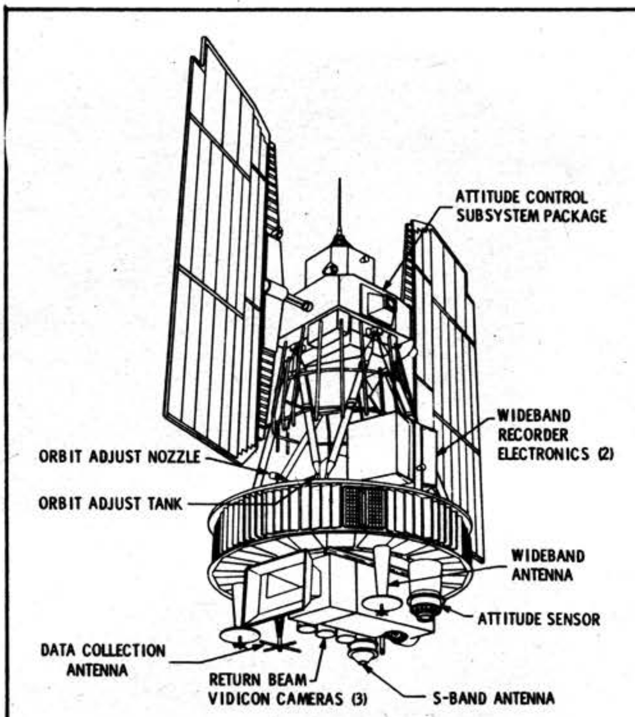
ERTS payload consists of two different imaging systems and a data collection system (the word image is preferred over photograph since no film return is involved). The first and simpler imaging system is the group of three return beam vidicon cameras (RBV).

In a sense the RBV is a cross between a film camera and a TV camera. A small telephoto lens projects the image of a 115 mile square on to a one inch square charged faceplate. An electron gun scans the faceplate and measures the energy of the returning electrons as altered by charged resistance in the faceplate. Since this scan process takes 3.5 seconds (covering 4500 lines as compared to 525 lines on conventional



In 1971 the US Department of Agriculture, NASA and corn experts in selected Corn Belt States conducted joint ground and air study of Southern corn leaf blight during the growing season. One of the aircraft used for this experiment was a USAF RB-57F which carried special research equipment to altitudes of up to 60,000 ft. The results obtained have been invaluable to the Earth Resources Technology Satellite programme. Although there is little the farmer can do to protect himself against corn blight at present, early warning may possibly give him time to protect his crop by spraying, or salvaging part of his crop by harvesting early, cutting for silage or destroying blighted areas quickly to keep the disease from spreading as rapidly as it otherwise would.

National Aeronautics and Space Administration



Earth Resources Technology Satellite. The spacecraft telemetry, tracking and command subsystems are designed to be compatible with stations from either NASA's Manned Space Flight Network (MSFN) or its Space Tracking and Data Acquisition Network (STADAN). Wideband payload data is received at MSFN sites (NTTF and Corpus Christi) and one STADAN site (Alaska). The Operations Control Center (OCC) is the focal point of system operations. Here the overall system is scheduled, spacecraft commands are originated and operations are monitored and evaluated. The NASA Data Processing Facility (NDPF) receives payload video data in the form of magnetic tapes and performs the video-to-film conversion, producing black and white copies of individual spectral images and colour composites. The NDPF includes a storage and retrieval system for all data and provides for various user services.

General Electrical Company of USA

TV) the RBV cameras cannot operate continuously. Instead, the faceplate can be exposed for 8, 12, or 16 milliseconds with a focal plane shutter. This works like the slit of a curtain moving across a window. Each of the 3 RBV's operates in black-and-white but, with filters over each, in different parts of the spectrum. The three operating bands – 4.75-5.75 microns (blue-green), 5.80-6.80 microns (red), and 6.90-8.30 microns (near infrared) – are closely comparable to the spectral bands for the Earth Resources Experiment Package scheduled to fly on Skylab this year. RBV resolution is 500 ft. and one picture cycle takes 25 seconds. Each frame overlaps the preceding one by 10%.

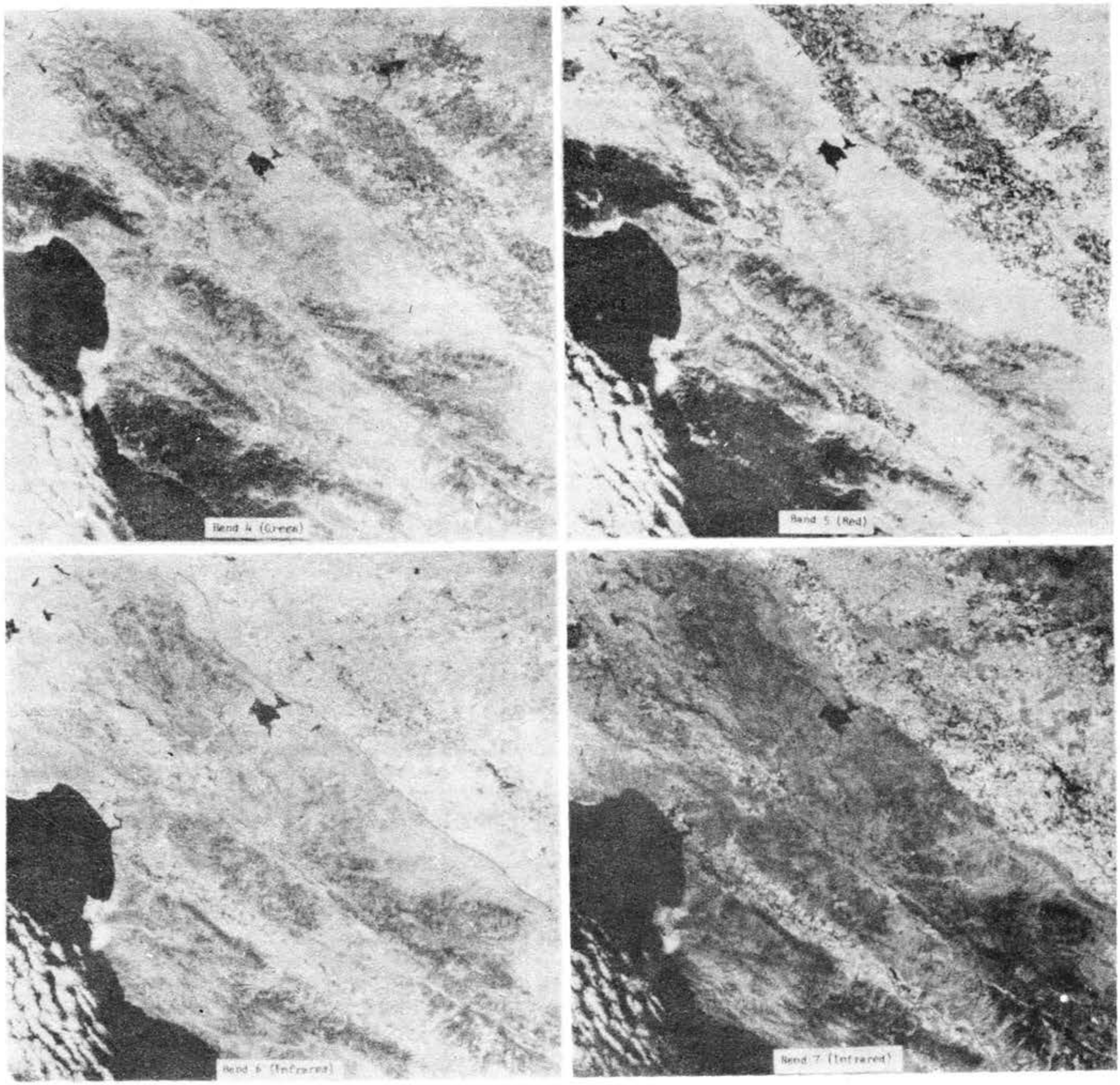
The other imaging unit is the Multispectral Scanner (MSS), basically a set of four groups of photomultiplier tubes sensitive to separate bands of light ranging continuously from 0.5 to 1.1 microns (green to near infrared). A fifth sensor, requiring passive cooling, will operate in the 10.4-12.6 micron region (thermal infrared) on ERTS-B. The tubes 'look' through a folded Cassegrain telescope giving a resolution of 225 ft. Since the tubes can only look at one spot (they operate through fibre optics) an oscillating mirror is used to give them a scanning view across the spacecraft's groundtrack. This produces a continuous strip image of the ground.

Data Collection System

Most of the last ERTS experiment literally did not get off the ground. The data collection system (DCS) is designed to relay data from remote stations to ground stations via ERTS. About 200 data collection platforms (DCP), small unmanned automatic radio stations, will be placed in remote or inaccessible areas where, connected to a small experiment package, they will transmit data on weather conditions, water quality, etc., depending on the experiment. The DCP transmits every 3 minutes, on 8 channels. When ERTS is above the horizon for a particular DCP the data is relayed immediately to a ground station. An experiment similar to the DSP was conducted 2 years ago when a radio transponder was placed on an elk in Minnesota. A Nimbus weather satellite would relay the data from the elk's radio, thus permitting continuous migrational tracking.

ERTS Orbit

ERTS was launched on 23 July from Vandenburg Air Force Base, California, by a Delta rocket with 9 solid motor



Four photographs of the Monteray Bay Peninsula taken by ERTS-1 on 25 July 1972. Although each picture shows the same area, they contain different types of information. The 'camera' which took this sequence is technically called a Multi-Spectral Scanner System (MSS). There are three colours in the MSS. Band 4 is green (surface water mapping); Band 5 is red (land use mapping), and Bands 6 and 7 are infrared (hydrology and agriculture/forestry). A picture composite of Bands 4, 5 and either 6 or 7 is a colour infrared image. The reason for splitting the infrared band is that the Band 6 is expected to show the effect of the onset of disease or insect attack on vegetation. Federal agencies participating with NASA in this project are the Department of Agriculture, Commerce, Interior, Defense and the Environmental Protection Agency.

National Aeronautics and Space Administration

strap-ons. The orbit achieved was 560 x 564 miles x 99.125° inclination with a 103 minute period. The 99° inclination produces a Sun synchronous orbit in which the precession of the orbit equals the Earth's motion about the Sun. This keeps the attitude of the orbit constant relative to the Sun, and the spacecraft always descends across the equator at 0930 local time. Because spacecraft precession and the Earth's motion do not match exactly there is a 1.4° westward shift of the 15th orbit which would otherwise duplicate the first. There is a 14% overlap, at the equator of the 15th and 1st groundtracks allowing total coverage of the Earth during the 18 days it takes for the orbit to again match the first one.

Image Processing

Processing 10,000 images a week is no easy task, particularly when each image requires precision work or it becomes worthless.

Data from ERTS is transmitted to 3 ground stations – Goldstone, California, Fairbanks, Alaska, and Goddard Space Flight Center in Maryland. Data tapes from Alaska and Goldstone are mailed to GSFC. At GSFC the image tapes can be processed in any of three manners. The end product typically will be a colour picture but of a type no organic eye could see. As mentioned before, the images from ERTS come down as black-and-white, one image per channel. These b&w images measure the reflectance of light in a particular band.

Normally these b&w images are meaningless to the eye, particularly since the eye is often unable to distinguish one shade of grey from another. But, by taking 3 different spectral images of the same object (either all 3 RBV images of 3 of 4 MSS images) and assigning each a different colour in a composite, a startlingly different picture of the original object emerges. For false-colour infrared pictures from the RBVs, the blue-green band is printed blue, the red band as green and the near IR band as red. One of the most pronounced effects of this is the appearance of vegetation as red and water as black. Healthy vegetation can be distinguished from sick by comparing their light 'signatures', since each planet has its own signature. Similar changes in appearance can be put to uses such as detection of blighted crops, crop inventories, etc.

Getting from the data tapes to the users' 9½ in. square colour prints or transparencies involves several steps. The most common pictures produced are system corrected (once called 'bulk processed'). An electron gun, guided by the data tapes, exposes 70 mm b&w film to produce RBV and MSS images (MSS images are broken down to a series of frames, with 10% overlap, rather than a continuous strip to make their use with RBV images easier). The gun can be commanded to correct for errors caused by known variations in each RBV, spacecraft attitude, etc. In addition, each frame is annotated with position markings, time, etc., on the perimeter of the image. The master 70 mm b&w film is then used to produce 9½ in. square b&w transparencies. These are then punched with holes in the corners so that, when each is in turn dropped on aligning posts on the colour printer, the images will register properly. Maximum misregistration is one-half a scan line. Colour prints are produced on continuous rolls of paper and processed automatically.

Scene corrected images (once referred to as 'precession processing') involves producing an image that is corrected to be orthogonal regardless of spacecraft attitude, mis-alignment of one RBV with respect to the others, lens variations, etc. Only about 455 scene corrected images will be produced each week – most of them for cartographers attempting to correct maps with ERTS images. Picture processing is the same as for system corrected images. System corrected 70 mm images scanned and known ground points, whose distances are precisely measured, are compard to produce corrections. From this new 70 mm images are produced, then colour prints.

The final form of data output is computer compatible 9 channel tape. Image data is stored here in digitized form rather than analog (as it is on the master tapes and transmitted from ERTS). This enables the investigator to produce images in accordancewith his own needs. One may wish to use but one MSS channel and produce false colour images from that with different colours corresponding to certain shades of grey. Or another may wish to use only one portion of the channel, i.e., only data indicating a certain range of reflectances.

Although no follow-ons have yet been approved, ERTS-C & D and others will probably use different payloads in order to evaluate different sensors. Some for example, could be more oriented towards oceanography. But, since NASA is primarily an investigating agency, any programme to apply remote sensing would have to be initiated by the Department of Interior. High resolution imaging systems would have to be cleared through the Defense Department which has thus far successfully blocked civilian use of a 12-in. camera (12 in. focal length) since this could reveal too much about spy satellite capabilities. A similar system, though, is now flying in the 'Big Bird' reconnaissance satellite. (An alternative mission for Apollo 15, in the event it could not leave orbit, was to use the lunar mapping cameras to map parts of the US. The Defense Department agreed to this only on the grounds that such pictures be classified).

The ERTS programme is not an end in itself. Coupled with aircraft photography, Skylab photography and experiments on other satellites it is really a massive calibration programme. ERTS will help to determine exactly what can or cannot be done from Earth orbit.

GENERAL REFERENCES

1. Bachofer, B.T. 'Earth Resources Technology Satellite System', General Electric Co., Space Systems, Western Electronic Show and Convention, Los Angeles, California, 27 August 1970.
2. Ragland, T. M. 'The Earth Resources Technology Satellite (ERTS) System', NASA/GSFC, Greenbelt, Maryland.
3. Buiten, R, Johnson R, 'Design of the ERTS Imaging Processing System', AIAA 8th Annual Meeting and Technical Display, Washington, D.C., 25-28 October 1971.
4. General Electric public relations pamphlets.
5. NASA Press Release.
6. Miller, B. 'Ground Tests Aid Multispectral Scanner', *Aviation Week & Space Technology'*, 31 July 1972.
7. Stein, K. J. 'Vidicon System Uses Three TV Sensors', *Aviation Week & Space Technology'*, 31 July 1972.
8. Klass, P. J. 'Data System to Serve Variety of Users', *Aviation Week & Space Technology*, 31 July 1972.

Acknowledgements

The author would like to make grateful acknowledgement to the following:

Jim Lynch, Goddard Space Flight Center, Public Affairs, Tom Ragland, ERTS Programme Office, GSFC, Dave Keller, ERTS Programme, General Electric and General Electric Public Affairs.

THE SKYLAB STUDENT PROJECT

By P. J. Parker

A group of B.I.S. members will witness the launching of the Skylab space station by a 2-stage Saturn V from Cape Kennedy Space Center on 30 April. They will also watch the lift-off of the first astronaut team on 1 May by a Saturn IB which has the task of docking with Skylab and boarding it for an initial stay of up to 28 days. Second and third manned missions will be for up to 56 days. Details of Skylab have been given in previous issues, e.g., *Spaceflight*, Sep. 1971, pp.335-337. This article describes an interesting sidelight of the project in which NASA invited the participation of students.

Introduction

The Skylab Student Project, jointly sponsored and conducted by the National Aeronautics and Space Administration (NASA) and the National Science Teachers Association (NSTA), was announced in 1971 to stimulate science and technology in US secondary schools. The project gave students the opportunity to directly participate in space research programmes by proposing experiments to be performed aboard the orbiting Skylab manned space station during 1973. The project was open to students in grades 9 - 12 in US public, private, parochial and US overseas schools.

Project Organisation

On 28 September 1971, NASA announced that it had selected the NSTA to jointly operate and manage the Skylab Student Project under a 19-month, $39,000 cost-reimbursement contract. The NSTA was to provide:

(a) Personnel, materials, facilities and services necessary for notification of the student and educational community of the opportunity and method of participating in Skylab;
(b) Develop the procedures for evaluation of proposals based upon educational value;
(c) Develop 'Certificates of Participation' and an award system for entrants;
(d) Develop plans and procedures for final selectees whose proposal ideas were selected by NASA; and
(e) Plan, organise and conduct a Skylab Student Education Conference at the Kennedy Space Center, for the 25 national selectees at the time of the Skylab launch.

The NSTA extensively advertised the project throughout US secondary schools using large, multi-coloured posters. These posters invited interested students, via their teacher or tutor, to request an official entry form, rules booklet and sample proposals from the NSTA national headquarters. Completed proposals were submitted to one of the twelve NSTA regional chairmen nearest to the students location (Table 1). Up to 10% of the entrants in these twelve areas were selected as regional winners by local selection committees, and these successful candidates were then judged by a national committee who prepared a short list of 25 candidate proposals suitable for flight aboard Skylab. The final selection was made by NASA officials in April 1972.

Table 1. List of NSTA Regional Areas

Region	Areas
I	Connecticut, Main, Massachusetts, New Hampshire, Rhode Island, Vermont.
II	New York State (excluding New York City).
III	New York City (all five boroughs).
IV	New Jersey, Pennsylvania.
V	Delaware, District of Columbia, Maryland, North Carolina, South Carolina, Virginia, West Virginia.
VI	Alabama, Canal Zone, Florida, Georgia, Mississippi, Puerto Rico, Tennessee, Virgin Islands.
VII	Indiana, Kentucky, Ohio.
VIII	Illinois, Missouri.
IX	Iowa, Michigan, Minnesota, Wisconsin.
X	Arkansas, Kansas, Louisiana, New Mexico, Oklahoma, Texas.
XI	Alaska, Colorado, Idaho, Montana, Nebraska, North Dakota, Oregon, South Dakota, Washington, Wyoming.
XII	Arizona, California, Guam, Hawaii, Nevada, Utah.

Certificates, Awards and Honours

The 3,409 students who, by the deadline of the 4 February 1972, had submitted experiment proposals received a Certificate of Participation. The selected regional area winners received an individual certificate, an official Skylab pin and certificates for their school and teacher-sponsor. The 25 national winners and their teacher-sponsors are being invited to attend the Skylab Education Conference and Awards Presentation Ceremony at the Kennedy Space Center at the time of the Skylab launch currently scheduled for 30 April 1973. The winners will also receive special medallions and a plaque for their school. The student (s) whose proposal (s) are finally selected for flight aboard Skylab will have the privilege of working alongside leading NASA officials in preparing their experiments for the mission.

Competition Entry Information Package

Students who requested, via their teacher, an official entry form received from the NSTA a competition entry information package. This package contained the official entry form, rules booklet, several sample proposals, Skylab programme description handbook and a fold-out wallchart.

(a) *Official Entry Form*

This double-sided printed sheet had to be completed to qualify students for consideration in the competition. It requested the student's or team-leader's name, age, school grade and home address; title of proposal; proposal category (i.e., on-board experiment, crew recreational activity or data utilisation); name of teacher/sponsor; teacher's address; school name; hometown newspaper (s); newspaper'(s) addresses (es) and signatures of the proposer (s) and teacher-sponsor.

(b) *Rules Booklet, 1971-1972*

This 12-page booklet outlined the Skylab Student Project, its purpose, competition entrance eligibility and the competition recognition structure. The booklet stressed that a proposal should:

(1) Clearly state its purpose, objectives or hypotheses with sufficient background

information to provide a rationale for the proposal;
(2) Describe the hardware required for the proposed activity;
(3) Detail procedures for carrying out the proposed experiment;
(4) Suggest methods for collecting data during the experiment; and
(5) Outline post-experiment data analysis plans.

The booklet also stressed that proposals should feature concepts which cannot be dealt with on Earth and which utilise one or more of the unique features of the Skylab facility i.e., zero-gravity, broad view of the Earth's surface and space operations. The booklet gave examples of suitable experiment concepts but suggested that students use accompanying information to gain the widest possible view of Skylab's capabilities.

Table 2. Skylab Student Project – 25 National Finalists

Student	Teacher	School	Proposal Title
D. C. Bochsler	J. P. Daily	Silverton Union High	Possible Confirmation of Objects within Mercury's Orbit.
K. M. Brandt	C. E. Martell	Grand Blanc Senior High	Chicken Embryology in Zero-Gravity.
V. W. Converse	M. J. Trumbauer	Harlem High	Zero-Gravity Mass Measurement.
T. A. Crites	R. C. Putnam	Kent Junior High	Space Observation and Prediction of Volcanic Eruptions.
W. B. Dunlap	P. J. Pallante	Austintown Fitch High	Wave Motion Through a Liquid in Zero-Gravity.
J. C. Hamilton	J. A. Fuchigami	Aiea High	Spectrography of Selected Quasers.
J. E. Healy	P. Mottl	St. Anthony's High	Universal Gravitational Constant.
A. Hopfield	N. Sperling	Princeton Day	Photography of Libration Clouds.
K. L. Jackson	M. K. Kimzey	Clear Creek High	A Quantitative Measure of Motor Sensory Performance During Prolonged Inflight Zero-Gravity.
R. G. Johnston	T. E. Molitor	Alexander Ramsey High	Capillary Action Studies in a State of Free Fall.
J. L. Leventhal	H. E. Choulett	Berkeley High	X-Ray Emission from the Planet Jupiter.
K. D. McGee	A. B. Patterson	South Garland High	Effect of Zero Gravity on the Colloidal State of Matter.
T. A. Meister	V. G. Galasso	Bronx High School of Science	An In Vitro Study of Selected Isolated Immune Phenomena.
G. A. Merkel	S. C. Economou	Wilbraham and Monson Academy	Brownian Motion and Dissolution of a Salt in Zero-Gravity.
J. S. Miles	J. M. Conley	Lexington High	Web Formation in Zero-Gravity.
C. A. Peltz	G. B. Scheels	Arapahoe High	Cytoplasmic Streaming in Zero-Gravity.
T. C. Quist	M. Stewart	Thomas Jefferson High	Earth Orbital Neutron Analysis.
J. W. Reihs	H. W. Boyd	Tara High	X-Ray Content in Association With Stellar Spectral Classes.
D. W. Schlack	J. C. Beaton	Downey High	Phototropic Orientation of an Embryo Plant in Zero-Gravity.
N. W. Shannon	P. H. Knappenberger	Fernbank Science Center	A Search for Pulsars in Ultra-violet Wavelengths.
K. M. Sherhart	H. L. Politzer	Berkley High	Testing Flow Properties of Powdered Solids in Zero-Gravity.
R. L. Staehle	A. H. Soanes	Harley	Behaviour of Bacteria and Bacterial Spores in the Skylab and Space Environments.
K. L. Stein	D. E. Unger	W. Tresper Clarke High	Effects of Intermittent Long-duration Exposure to Zero and Artificial Gravity.
J. G. Wordekemper	L. M. Schaaf	Central Catholic High	Plant Growth in Zero-Gravity.
J. B. Zmolek	W. L. Behring	Lourdes High	Earth's Absorption of Radiant Heat.

In other sections the booklet rules on how proposals should be submitted, and gives details of the announcement of winners, lists the 12 regional areas and includes Skylab guidelines and constraints. These latter notes were intended to familiarise students and teachers with an awareness of major factors to be considered such as safety, configuration and environment, flight compatability and system and mission plans.

(c) *Sample Proposals*
Examples of complete proposals were included in the information package to serve as guides to students in their experiment proposals. Completed proposals submitted by students were not to exceed 1,000 words and were to be double-spaced typed on one side of 8½ x 11 in. plain white paper. The sample proposals included in the package served as examples of layout with such headings as Objectives, Hardware description, Protocol and Data review. The titles of the sample proposals were 'Zero-gravity Thermal Flow in a Fluid', 'Aerodynamic Stability Experiment', and 'Zero-gravity Ova Development in Drosophilia'.

(d) *Skylab Programme Description Handbook*
This NASA 64-page handbook provided a digest of information about the Skylab Programme with descriptions of the unique Skylab features (e.g., zero-gravity); missions, vehicles and systems; experiments and a detailed Skylab acronym listing. The handbook was illustrated with cut-away drawings of major Skylab elements (e.g., Orbital Work Shop, Apollo Telescope Mount) and with general photographs and other illustrations.

(e) *Fold-out Wallchart*
This excellent fold-out wallchart, size 30 by 22 inches, was prepared by Martin-Marietta Corporation, a major Skylab programme contractor to NASA. This colourful chart included a description of the programme objectives, Skylab elements, NASA and contractor roles and responsibilities, mission profiles, mission events and a tabular listing of the flight experiments. When unfolded the chart revealed a magnificent artist's-impression of the Skylab cluster in orbit above the Earth. Above this drawing were smaller sketches of each element of Skylab with associated notes on its systems and experiments.

Student Finalists

Up to 26 January 1972, over 80,000 student requests for entry materials had been received by NSTA national headquarters and, by the deadline of 4 February 1972, some 3,409 completed proposals had been submitted by US secondary school students for consideration. On 6 April 1972 NASA/NSTA officials selected the 25 national finalists from whom the final choice of flight experiments and demonstrations would be chosen. The 25 finalists and their proposals are outlined in Table 2.

The high standard of the final proposals chosen by NASA/NSTA is indicated by the following examples. Judith S. Miles, Lexington High School, suggested that the astronauts let a spider spin a web in the weightless environment of Skylab and that this web should be compared with a spider's web spun on Earth. Kent M. Brand, Grand Blanc Senior High School, described equipment for observing fertilised chicken eggs in weightlessness until they hatched. Joel G. Wordekemper, Central Catholic High School, suggested growing radish seedlings in Skylab to find out whether roots, in weightlessness, grow downward toward the Earth and stems grow upward away from the Earth, as they do on Earth. A proposal entitled 'Cytoplasmic Streaming in Zero-Gravity' was submitted by Cheryl A. Peltz, Arapahoe High School. This experiment would set out to determine the effects of weightlessness on the mechanism which transports and distributes energy in plant cells and without which cells die. Another finalist, Troy A. Crites, Kent Junior High School, proposed that Skylab astronauts photograph volcanoes with infrared film, which senses temperature differences rather than light gradations. He suggested that the build-up of heat and pressure inside a volcano might be detected and eruptions predicted in advance to protect life in the vicinity. He pointed out that infrared equipment is already installed aboard Skylab for 'official' experiments.

Conclusions

As an exercise in stimulating science and technology studies among students the Skylab Student Project, organised and conducted by the NASA/NSTA, has had phenomenal success. The number of completed proposals received by the NSTA, was the largest that it has ever received for any of its competitions. It is obvious that students are willing to directly take up the challenge of space. With the introduction of regular Space Shuttle flights and daily operations aboard the 10-year manned Modular Space Station in the 1980's, it is possible that similar student space project competitions may be organised on an annual basis. Perhaps such competitions by then will have become international in scope, with finalists from many nations competing for experiment space. Ideally, such international competitions would be organised by the International Astronautical Federation (IAF) in conjunction with astronautical societies, such as the British Interplanetary Society and national educational organisations. These latter bodies would conduct 'knock-out' competitions to select national candidates for the international final. Who knows, with the introduction of regular shuttle flights, the 'grand prize' could be the opportunity to ride into orbit. The international winner might then actually conduct his experiment in the space environment!

Acknowledgements

The author wishes to thank the staffs of the National Aeronautics and Space Administration (NASA), Educational Programs Division; the National Science Teachers Association (NSTA); the United States Information Service, London; and NASA's European Representative Office, Paris, for material used in this article. In particular, he wishes to thank Kenneth Atchinson (NASA Office of Public Affairs), Robert S. Tiemann (NASA EP Division), Robert E. Bernier (NASA European Representative), Mrs. Dorothy K. Culbert, (NSTA) and William Dunn (USIS); also L. J. Carter, BIS Executive Secretary, for the inspiration he has provided over several years in the field of space education.

RESCUE FROM SKYLAB

When Skylab is placed in Earth orbit this year, the first limited capability to rescue astronauts in space will become a reality. In the experimental space station three-man crews will conduct scientific, technological, and biomedical investigations. The first manned mission will last up to 28 days; the second and third 3-man missions are planned for 56 days.

In the Mercury and Gemini programme, the spacecraft could not be used for rescue because of their restricted size and life-support capability. A different and unique spacecraft would have been necessary to retrieve stranded astronauts.

In the Apollo programme, rescue capability was again not feasible because of the limited life-support capacity of the lunar module coupled with the time required for the command and service modules to travel from Earth to the Moon. A rescue vehicle standing by in lunar orbit would have been necessary for lunar orbit rescue but still could not pick up astronauts on the lunar surface.

With Skylab, the orbital workshop offers long-duration life support in Earth orbit and a practical rescue capability is feasible. In each of the three visits, astronauts will be flown to the space station in a modified Apollo command and service module (CSM). The CSM is powered down after docking and Skylab activation remains available for life support and crew return in the event of an Orbital Workshop (OWS) failure. Therefore, the only failures to be considered for rescue requirements are loss of CSM return capability or the loss of accessibility to the CSM. In this event, a second CSM would be launched carrying only two men with room for the three astronauts to be picked up in orbit and the rescue CSM would then return with a crew of five.

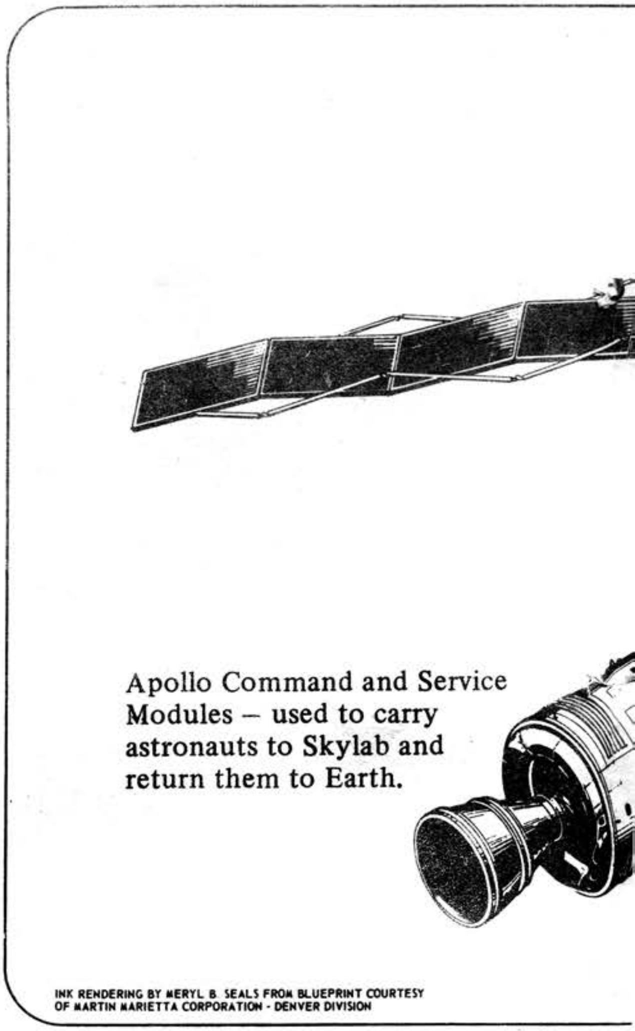
The three Skylab manned launches are about 90 days apart. Therefore, after each of the first two manned launches, the next vehicle in normal preparation for launch would be used for rescue, if needed. After the third and final manned launch, the Skylab backup vehicle would be made ready for possible use as a rescue spacecraft.

Just how long the Skylab astronauts would have to wait for rescue depends on the point in the mission when the emergency develops. The wait in the well-supplied Orbiting Workshop could vary from 48 to 10 days.

If, for instance, the need for rescue arose on the first day of the Skylab's occupancy or reoccupancy, present work schedules indicate that it would take 48 days for the launch crews to prepare the rescue launch vehicle and spacecraft. This includes 22 days required to refurbish the launch tower following the previous launch. During this period the rescue kit would be installed in the CSM, a task which takes about 8 hours, and the entire vehicle then prepared for stacking. After being moved to the launch pad for final checkout and servicing the countdown, which requires about a week, would begin.

The later into a mission the need for rescue occurs, the sooner the vehicle would be ready for launch. The launch-response time from alarm is reduced to 28 days and 10 days at the end of the first and third missions, respectively.

The standard Skylab CSM accommodates a crew of three with storage lockers on the after bulkhead for resupply of experiment film and other equipment as well as the return of exposed film, data tapes, and experiment samples. To convert the standard CSM to a rescue vehicle, the storage

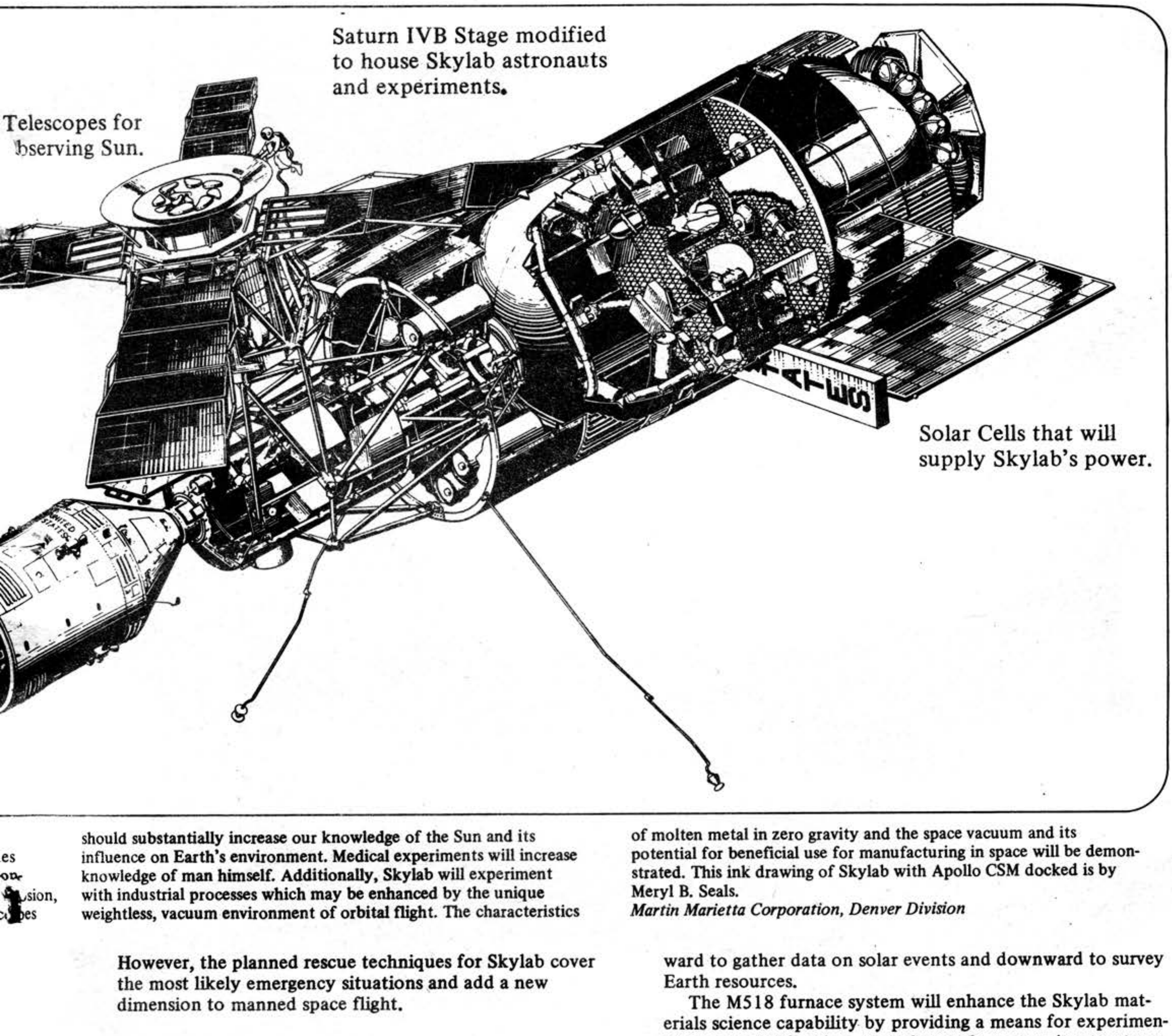


SKYLAB, America's first manned space station, has multiple objectives in science and technology. It will evaluate techniques designed to gather information on Earth's resources and environmental problems such as pollution of air and water, flooding, weather, crop deterioration, and mineral deposits. Solar telescope

lockers are removed and replaced with two crew couches in order to seat five crewmen. The rescue CSM would then be launched with a crew of two.

Shortly before rescue, the stranded Skylab crew would don pressure suits and enter the multiple docking adapter (MDA), seal it off from the remainder of the cluster and depressurize it. Then they would install a special spring-loaded device to separate the disabled CSM from the axial (end) port of the MDA at sufficient velocity to move it out of the way of the arriving rescue CSM. It is not essential, however, that the disabled CSM be separated from the axial port. The arriving CSM can dock, if necessary, with a radial (side) docking port in the MDA. In this position, which is a contingency arrangement, limited but sufficient stay time is available for full rescue operations.

Providing rescue facilities under all conceivable emergency situations would require instantaneous response, a capability not feasible with present space vehicles because of elaborate launch preparations. Faster response must await a new generation of space transportation such as the space shuttle.



es
on
sion,
es

should substantially increase our knowledge of the Sun and its influence on Earth's environment. Medical experiments will increase knowledge of man himself. Additionally, Skylab will experiment with industrial processes which may be enhanced by the unique weightless, vacuum environment of orbital flight. The characteristics of molten metal in zero gravity and the space vacuum and its potential for beneficial use for manufacturing in space will be demonstrated. This ink drawing of Skylab with Apollo CSM docked is by Meryl B. Seals.
Martin Marietta Corporation, Denver Division

However, the planned rescue techniques for Skylab cover the most likely emergency situations and add a new dimension to manned space flight.

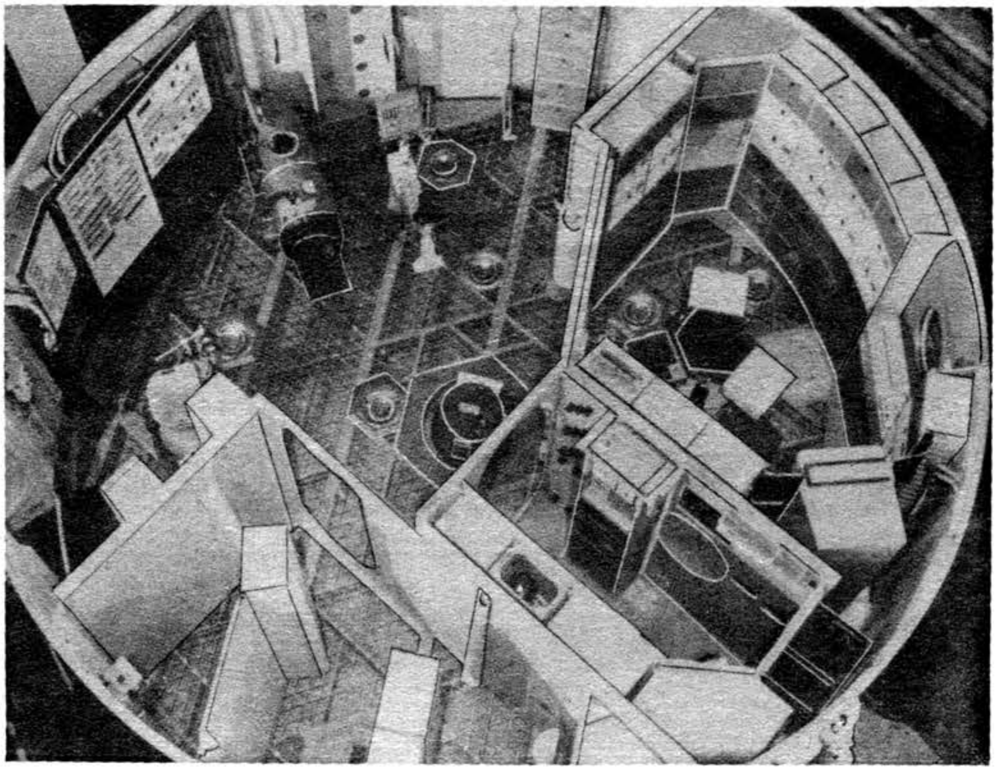
ORBITAL FURNACE

Ten additional experiments in metals and materials processing will be conducted by astronauts aboard Skylab. The added experimental capability was made possible by the development of the M518 Multipurpose Electric Furnace System to replace the composite casting furnace. The new furnace, taking no added space, weight or volume, will accommodate the original composite casting experiment and ten others.

Skylab, to be launched by NASA on 30 April, is an orbital research laboratory in which the astronauts will carry out a wide variety of scientific, engineering and biomedical experiments. Among other tasks, Skylab instruments will look skyward to gather data on solar events and downward to survey Earth resources.

The M518 furnace system will enhance the Skylab materials science capability by providing a means for experimentation in solidification, crystal growth, composite structures, alloy structural characteristics and other thermal processes involving changes in materials under conditions of weightlessness. It increases the number of Skylab metals and materials processing experiments from 7 to 17.

The NASA-Marshall Space Flight Center, Huntsville, Alabama, is responsible for the M518 furnace system with Westinghouse Corporation, of Pittsburgh, as the principal contractor. Westinghouse produced the furnace and equipment required for the experiments. The furnace itself is 10.16 cm. (4 in.) id diameter and 29.21 cm. (11.5 in.) long. The furnace and supporting equipment occupies about .042 m^3 (1.5 ft^3) of space and weighs 21.6 kg. (47.5 lb.). It is capable of reaching and holding selected temperatures up to 1,000°C. (1,832°F.) and achieving variable programmed 'cool down' rates.



Left, overhead view of the Skylab crew quarters in the Orbital Workshop mockup/trainer at the George C. Marshall Space Flight Center, Huntsville, Alabama. Clockwise from upper right are the work compartment, ward room, waste compartment and sleep compartment.

National Aeronautics and Space Administration

Right, maintaining equilibrium. Using a revolving litter chair, which can be adjusted to a horizontal position, the effects of weightlessness and sub-gravity conditions on astronaut perception, motion sensitivity, orientation, and balance can be investigated. This will help to determine the need for artificial gravity in future space flights.

United States Information Service Service

Manufacturing and processing techniques not possible on Earth may be possible in zero gravity. The Skylab experiments in M518 will explore and pioneer some of these potentially practical uses. The 11 experiments, their objectives and principal investigators are:

M556 – Vapour Growth of II-VI Compounds:
To determine the degree of improvement that can be obtained in the perfection and chemical homogeneity of crystals grown by chemical vapour transport under weightless conditions. Dr. Harry Wiedemeier, Rensselaer Polytechnic Institute, Troy, New York.

M557 – Immiscible Alloy Compositions:
To determine the effects of near zero-gravity on the processing of material compositions which normally segregrate on Earth. Jo Reger, TRW Systems Group, Redondo Beach, California.

M558 – Radioactive Tracer Diffusion:
To measure self-diffusion and impurity diffusion effects in liquid metal in space flight and characterize the disturbing effects, if any, due to spacecraft acceleration. Dr. Anthony O. Ukanwa, NASA – Marshall Space Flight Center.

M559 – Microsegregation in Germanium:
To determine the degree of microsegregation of doping impurities in germanium caused by convectionless directional solidication under conditions of weightlessness. Dr. Francois Padavani and Dr. Fred Voltmer, Texas Instruments Corporation, Dallas.

M560 – Growth of Spherical Crystals:
To grow doped germanium crystals of high chemical homogeneity and structural perfection and study their resulting physical properties in comparison with theoretical values for ideal crystals. Dr. Hans Walter, University of Alabama at Huntsville.

M561 – Whisker – Reinforced Composites:
To produce void-free samples of silver and/or aluminium reinforced with oriented silicon carbide whiskers. Dr. Tomoyoshi Kawada, National Research Institute for Metals, Tokyo.

M562 – Indium Antimonide Crystals:
To produce doped semiconductor crystals of high chemical homogeneity and structural perfection and to evaluate the influence of weightlessness in attaining these properties. Dr. Harry Gatos, Massachusetts Institute of Technology, Cambridge. Massachusetts.

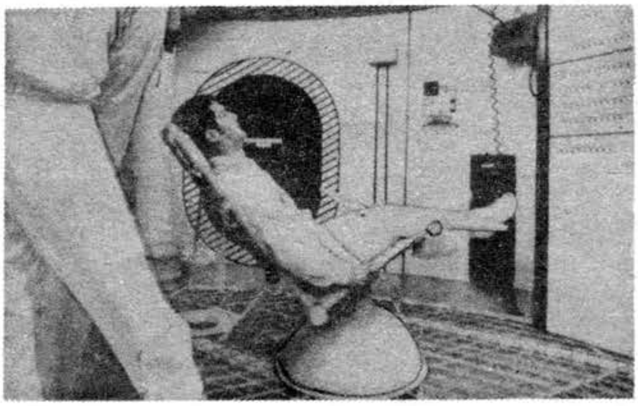
M563 – Mixed III-V Crystal Growth:
To determine how weightlessness affects directional of binary semiconductor alloys and, if single crystals are obtained, to determine how their semiconducting properties depend on alloy composition. Dr. William R. Wilcox, University of Southern California, Los Angeles.

M564 – Metal and Halide Eutectics:
To produce highly continuous controlled structures in samples of the fibrelike sodium fluoride-sodium chloride and platelike bismuth-cadium and lead-tin eutectics, and to measure their physical properties. Dr. Alfred Yue, University of California at Los Angeles.

M565 – Silver Grids Melted in Space:
To determine how pore sizes and pore shapes change in grids of fine silver wires when they are melted and resolidi-

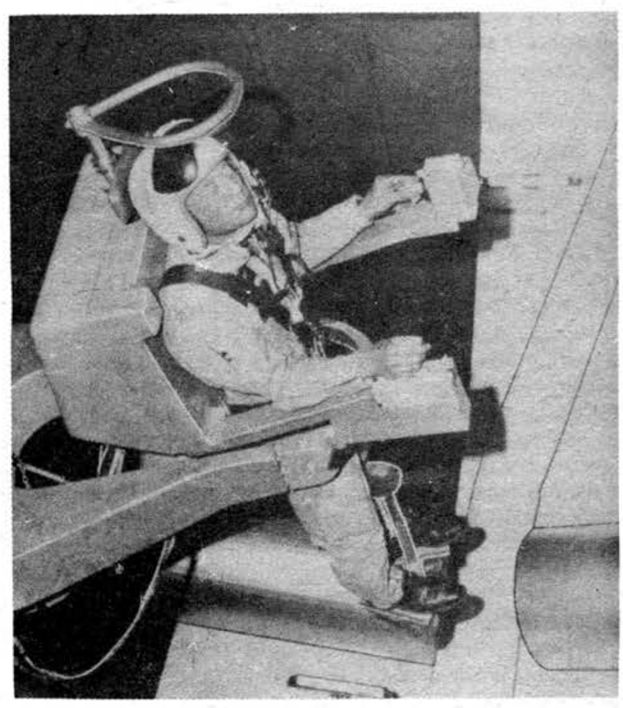
fied in space. Dr. A. Deruytherre, Catholic University in Belgium, Heverlee, Belgium.

M566 – Copper – Aluminium Eutectic:
To determine the effects of weightlessness on the formation of lamellar structure in eutectic alloys when directionally solidified. E. A. Hasemeyer, NASA-Marshall. (This replaces the M554 – Composite Casting experiment).



Top Right, heart and blood vessels. A slight suction applied to the lower half of the astronaut's body places a stress on his heart and blood vessels. Responses to this before, during and after the Skylab mission will provide information concerning cardiovascular accommodation during long duration space flight.

United States Information Service



Right, astronaut Edwin E. Aldrin, Jr., 'flies' the Astronaut Manoeuvring Unit (AMU) during tests at the Martin Marietta Corporation space operation simulator. In Skylab astronauts will use the AMU to test man's ability to move about in weightlessness with power-assistance.

Martin Marietta Corporation

SATELLITE TRIANGULATION

What is the distance between an established point in Washington D.C., and another on the island of Kyushu in Japan? Between points in Denmark and Ecuador, New Zealand and Ethiopia? Between Iran and Thailand?

Ever since it was known that the Earth is round, scientists have wanted to know its exact size and shape. Because they lacked that knowledge and had no reliable way of finding out, even modern maps of large areas are inaccurate, sometimes by as much as several kilometres, writes Walter Froelich. Beginning this year, scientists can give answers accurate to within 10 metres. For many points on Earth several thousand kilometres apart the distance can be calculated with an error of at most five metres.

An unprecedented six-year Earth-measuring programme is nearing its end. Participating have been 32 nations, including at least one from every continent.

It is the first massive Earth-mapping effort employing three major technological tools developed to their present state of sophistication within the last decade – a computer, an Earth satellite and atomic clocks. The millions of mathematical calculations required in the project are nearing completion at the computer centre of the US National Oceanic and Atmospheric Administration (NOAA) in Suitland, Maryland, a suburb of Washington,D.C.

The project, for which planning began late in the 1950's, consists of thousands of measurements made during 1966 through 1970. The two years since then have been spent in processing the information with the computer.

The key to the precision of the measurements is a technique called 'satellite triangulation.' It involves a 135-ft. diameter balloon named Pageos orbiting the Earth on a nearly circular path from pole to pole at an altitude of about 2,500 miles. The name Pageos is a contraction for Passive Geodetic Satellite.

Camera teams stationed themselves about 2,500 miles apart and, timing their shutters with atomic clocks, photographed the satellite at precisely the same moment. Pictures were taken while it was night at the photography sites but while the sides of the satellite facing Earth were illuminated by the Sun. The pictures show the satellite as a tiny dot of light against a dark, star-filled sky.

The pictures, though taken simultaneously, show Pageos in a slightly different location among the stars because each photograph was made from a different site. From that difference, scientists can calculate the precise distance between the photography sites.

Such measurements were made from 45 photography sites in 24 nations and the Artic and Antartic. In eight other nations, ground measurements were made to supplement the information obtained from the satellite pictures. Many of these ground measurements were made with a laser geodemeter, a new electronic tool using a concentrated light beam to determine distances. Twenty camera teams worked on the project. Fourteen from the United States, two from West Germany and one from the United Kingdom travelled around the Earth from site to site while two teams in Australia and one in South Africa worked at sites in their own countries. At least two teams had to work together for any one picture series. At locations where it was difficult to transport the bulky atomic clocks, the teams used portable quartz clocks which also keep time accurately to within 10 millionths of a second.

Pageos was launched in June 1966 especially for this project. For experimental purposes, the photography teams also used satellites Echo 1 and Echo 2, which were launched for communications purposes, because they were also balloon satellites, reflected sunlight sufficiently to be easily photographed.

All information produced in the project has been collected by NASA for publication and dissemination around the world to scientists and officials who can use it. Besides determining the size and shape of the Earth and permitting calculation of distances between points on Earth with a precision never achieved before, the project is bringing about the establishment of what specialists call the first global 'geodetic network'. That is a set of common 'datums' or reference points throughout the Earth. A 'datum' is a mathematical base which enables surveyors to define precise horizontal and vertical positions on Earth.

J.Donald D'Onofrio of the US National Geodetic Survey, who directed the project's field work, said that the project is expected to devlop a unified 'datum' for the Earth.'For the first time, the Earth's continents and most major islands will then be joined in a common 'datum' to which their 'datums' can be adjusted,' he said.

Nations from whose territory camera teams took satellite pictures include Denmark, Portugal, Surinam, Ecuador, Japan, Iran, Argentina, Italy, Chile, Australia, New Zealand, Mexico, United Kingdom, Ethiopia, Senegal, Chad, West Germany, Brazil, South Africa, Thailand, Mascarene Islands, Philippines and the United States. Ground measurements pertaining to the project were also carried out in Austria, Cameroon, Mali, Niger, Nigeria, Sudan, Sweden and Upper Volta.

SPACE NAVIGATION

The United States Air Force's Space and Missile Systems Organisation (SAMSO) awarded two contracts in January for design, fabrication and laboratory test of spaceborne landmark trackers for use in an autonomous spacecraft navigation system, writes Geoffrey Falworth. According to SAMSO engineers, perfection of landmark tracking is the only serious obstacle to devlopment of autonomous spacecraft navigation systems.

Under a previous SAMSO contract, IBM Inc., TRW Systems Group and Honeywell Inc., submitted separate system design schemes which identified components needed for a non-radiating, ground-independent, real-time autonomous spacecraft navigation system. All three contractors identified five major system components: an attitude reference system, precision clock, on-board computer, auxiliary sensors such as a radar altimeter, and a landmark tracker. The computer would process data received from the on-board sensors and provide Earth-centered inertial co-ordinate position information to ground controllers on command. SAMSO officials say that such a system would lighten the load on ground controllers and relieve them of part of the complicated and time-consuming job of determining spacecraft location using radar. Performance goals listed by SAMSO for an autonomous navigation system include accurate position determination on the first orbit.

Two landmark tracker designs will be chosen for fabrica-

tion and laboratory tests; however, the two will not necessarily come from IBM, TRW or Honeywell. 'We are trying to develop landmark tracking technology and are open to suggestions from the entire industry' according to a SAMSO project officer.

The Honeywell design is a strapped down, optical, unknown-landmark tracker using a solid-state silicon detector. It will look at contrast patterns of land masses that pass through its field of view and feed that information to an on-board computer. TRW prefers a gimballed, optical, unknown-landmark tracker employing an image-dissector cathode ray tube: the tracker would lock on a single scene and track it until the sensor's gimballing limits are reached, then lock onto another scene. The TRW design also acts as a star tracker. In contrast, IBM's design is a strapped-down, known-landmark tracker which would key on the back lobes of over 500 S-band radar installations around the world. IBM chose the S-band radar due to its weather penetration characteristics and further restricted the catalogue of known installations to those that would normally work 24 hr. a day.

All three designs are limited by the absence of suitable landmarks over some portions of Earth, according to SAMSO. Vast ocean expanses offer no stable contrast patterns for the TRW and Honeywell optical trackers, which would also be hampered by darkness and clouds. The IBM radar tracker suffers from a lack of suitable S-band radar installations in some parts of the world.

SAMSO engineers say they could have a landmark tracker ready for flight test as early as 1975 if current plans produce the expected technological results.

GERMAN ROCKET ENGINES

Messerschmitt-Bolkow-Blohm claim that the MBB 'high-pressure topping cycle engine designed for use in Europa 3 is among the most efficient in the world.' They also state that 'the combustion chamber design developed by MBB has been adopted by the USA for use in the Space Shuttle Programme.'

'As early as 1956 the topping-cycle principle was seen by MBB as the most suitable design for high-pressure engines,' the company said. 'This principle permits the attainment of extremely high pressures in the rocket's combustion chamber with very little loss. The high efficiency combined with the small dimensions of a high-pressure engine, make it eminently suitable for use in space missions. The world's first integrated topping-cycle engine was initially tested in 1963 – at that time supported by the German Defense Ministry – in Ottobrunn near Munich. It had a thrust of 5,000 kp.

In 1967-68 the first cryogenic (liquid oxygen or fluorine in combination with LH_2) high-pressure engine in the Western World was developed in co-operation with North American Rocketdyne, now contractor for the Orbiter engines. Numerous tests with this 13,000 kp engine designed and built by MBB were made on the Rocketdyne test stands in the USA. Among other results, the stability of the copper combustion chamber developed by MBB using new type of galvanic process was demonstrated at combustion chamber pressures of up to 282 atm. – a performance unequaled at that time. This also showed that the severe cooling problems could be mastered.

Alongside high-pressure topping cycle engines utilizing cryogenic propellants, MBB developed high-pressure combustion chambers for rocket engines using storable propellants achieving high specific impulses,' the statement concludes.

Development work on the Europa 3 H-20 second stage engine has been in progress since 1970 within the scope of Cryorocket, a joint interest group of MBB and SEP (Societe Europeene de Propulsion) of France.

COLLOID THRUSTERS

A tiny colloid propulsion system that provides a millionth of a pound of thrust has completed more than 1,100 hr. of continuous operation – the longest firing of a one-millipound colloid rocket engine on record. The minieagle thrusters are being developed by TRW for the US Air Force Rocket Propulsion Laboratory at Edwards AFB, California, for use on future satellites requiring north-south station keeping, such as communications, weather and other satellites in geo-stationary orbits. Completion of the 1,100 hr. test marked the successful end of Phase 1 of the Air Force programme. It was conducted on a full-size breadboard model (about one cubic foot) with 12 thruster modules. Engineers at TRW's Applied Technology Division voluntarily terminated the test to evaluate the thrusters, propellent supply system, power control system, and other elements which make up the propulsion unit.

The test just completed is equivalent to approximately five months of north-south station keeping for a 2000 lb. satellite. A paralled test of a single thruster module (1/12th millipound thrust) was still in progress late last year after more than 4,000 hr. of operation.

Next phase calls for development of a flight-qualified version. A third phase will involve ground tests of three systems for 10,000 hr. each. Final phase of the programme requires TRW to deliver three flight units to the Air Force for testing aboard satellites.

Colloid thrusters operate on the principle of electrostatic propulsion, where small droplets of propellent are electrically charged, then accelerated by a high-voltage electrical field. Two units on a satellite would require about 65 watts of power, weigh about 90 lb. and carry enough propellent to provide station keeping for seven years.

ESRO 4 IN ORBIT

The ESRO 4 spacecraft launched from the Western Test Range by a 4-stage Scout rocket on 22 November, carries 5 experiments to study particles in the vicinity of the Earth. The near polar orbit ranged between 280-1,100 km with a period of 98 minutes. At orbital insertion ESRO 4 was spun at 150 r.p.m.; three radial booms then reduced the spin rate to 65-70 r.p.m. A command operated magnetic torquer was available to manoeuvre the spacecraft into any one of the five different attitudes required by the scientific experiments. Prime contractor for the spacecraft was Hawker-Siddeley Dynamics under contract from ESRO.

The British experiment in the 115 kg satellite, mounted by University College London's Mullard Space Science Laboratory at Holmbury St. Mary, Dorking, measures the density, temperature and composition of ions in the F-region of the ionosphere using 3 sensors. The main sensor is a gridded spherical ion collecting probe, 200 mm in diameter,

mounted on a 1.3 metre support boom to keep it out of the charge cloud surrounding the spacecraft; its potential is swept repeatedly from negative to positive voltages to enable it to act as an ion mass spectrometer. A much smaller probe, only 10 mm in diameter, is mounted on the same boom and collects electrons as its potential is swept above and below spacecraft potential.

Characteristic variations in the electron current show when the probe is at space potential, so indicating the spacecraft's own potential relative to space; this information is essential to the interpretation of the mass spectrometer's measurements.

A third spherical probe, 100 mm in diameter, is mounted on a 0.35 metre axial boom protruding from the base of the satellite. The probe carries a constant negative potential with respect to the spacecraft so that a total ion current may be measured as a check on the constancy of the ion density during each mass sweep of the spectrometer. A novel feature is incorporated in the measuring circuits to set the output at mid scale at the beginning of each mass sweep; in this way short period fluctuations of ion current as low as 2% may be detected whatever the ion density.

The other experiments in the spacecraft are provided by Physikalisches Institut, University of Bonn; Kiruna Geophysical Observatory, Space Research Laboratory, Utrecht, and the Max Planck Institut, Garching-Munchen.

Compagnia Generale di Elettricita (CGE), General Electric Company of the USA's affiliate in Italy, designed and manufactured the critical power supply system for the ESRO-4. This included a 20-cell, 6 amp/hr. nickel cadmium battery, 2 converters and a power switching unit. The switching unit contains integrated circuit logic for controlling battery charge from solar cells, for Sunlight/darkness operation, and for protection of the circuitry from surges of voltage and current.

The power supply system furnishes the electrical power needed by the satellite to perform the full range of scientific experiments including: (a) ion studies; (b) studies of neutral gas in the upper thermosphere and exosphere of the Earth; (c) studies of low-energy particles in the auroral zones; (d) measurement of polar cap absorption of high energy particles, from the Sun; (e) measurement of solar flare particles, and (f) space flight qualification of a European-built infrared horizon sensing equipment.

LABORATORY-PRODUCED 'LUNAR ROCK'

Lunite, a twin of the lunar rock regolith, has been produced at the Institute of Space Research of the Soviet Academy of Sciences. The scientists said in an interview with *'Sotsialisticheskaya Industriya'* that in the experiment they were more interested in the initial rather than the final result. To obtain lunite in laboratory conditions one must have a good idea of the processes which are conducive to its formation under natural conditions of the Moon and to be able to simulate these processes.

Regolith is a loose material consisting of dust, sand, bedrock particles, fragments of falling meteorites and various vitreous particles. Some scientists maintain that it is brought into being as a result of the fall of micrometeorites which penetrate the Moon's surface at a velocity of up to 72 km/sec. In the opinion of Soviet geochemists, among them Academician Alexander Vinogradov, one must also take into consideration other processes such as lunar volcanism. The experiment gave an opportunity to check different theoretical models.

Lunite was obtained in a special apparatus which made it possible to simulate many of the processes which occur on the lunar surface. It included pressure chambers with all kinds of mechanisms instruments and sensors to ensure high and low temperatures, corresponding to lunar conditions, as well as vacuum.

The fall of micrometeorites was imitated by a laser beam. A volcanic eruption occurs in a crucible made of tungsten filament containing salt through which electric current was passed to create a temperature of 1200-1800° in a vacuum. When the basalt started to boil gaseous helium was injected into the bottom of the crucible and helium jet ejected the boiling basalt upwards in the form of a miniature volcano, and a spurt of fire was allowed to hit a refrigerated glass plate which simulated the frigidity of space.

The newly-obtained substance, which was produced in a pressure chamber, is dark grey in colour, loose and easily agglutinating. It is an almost 100% analogue of the natural regolith from the lunar 'seas'.

PROFIT FROM SPACE

Soviet cosmonaut Konstantin Feoktistov believes that in the future man will be able to influence natural phenomena with the help of space techniques, e.g., dispell hurricane foci and modify the weather. Interviewed by *'Komsomolskaya Pravda'* on the 15th anniversary of the first Sputnik, he said, applied astronautics would bring great profit. A stable space communications system was cheaper than laying cables and building ground relay stations, and weather and navigation satellites were already supplying information not obtainable on Earth.

Feoktistov did not think it possible in our time to begin exploitation of the natural resources of the planets to meet the needs of the Earth. However, he stressed the importance of widening the exploration of the Universe and 'for this purpose big orbital stations with unique astrophysical instruments to function in interplanetary space have to be set up. Such stations should be assembled in outer space'.

'The construction of spacecraft increases considerably our chances of gaining more knowledge of the Universe'. Feoktistov went on. 'But astronomical facts are not the only things to be sought by man. It is quite possible that the way to explore the Universe is by studying the world of elementary particles'.

STUDY OF MIGEA METEORITE

A complex polymer compound, an analogue of polynucleotide, has been isolated by Soviet scientists Alexander Vinogradov and Gennady Vdovykin, from a sample of the Migea meteorite. This meteorite belongs to the class of carbonaceous chondrites in which specialists have found various organic substances in recent years.

The new compound from the Migea meteorite has a structure somewhat resembling the DNA which is included in the composition of living organisms.

Studies of organic compounds in carbonaceous chondrites

are of great interest for determining the conditions in which complex organic compounds formed before the origin of life. These meteorites are enriched with organic compounds that originated in them at an early period of the formation of the Solar System.

However, the twin spiral of the polymer's structure of the new meteorite is symmetrical, as distinct from the structure of DNA. The authors of the study believe that this difference points to the non-biological, chemical nature of the meteorite compound.

The presence of the analogue of polynucleotides (DNA and RNA) in the carbonaceous chondrite of the Migea, which is of a chemical nature, also shows, the scientists say, that in the protoplanetary gas-dust cloud there were favourable conditions for its natural synthesis. They hold that the synthesis of organic compounds from simple initial substances took place in conditions of not very high temperatures after the formation of chondrules (silicate grains) of which the meteorite consists.

Cosmic radiation could have served as the energy source of the synthesis. Polynucleotides similar to the ones found in the Migea meteorite could have been synthesised chemically also in terrestrial conditions before the origin of living matter, Vinogradov and Vdovykin believe.

A detailed report on this study has been published in *'Doklady Akademii Nauk SSSR'* (Proceedings of the Academy of Sciences of the USSR).

SAMSO SATELLITE PLANNED

U.S. Air Force's Space and Missile Systems Organisation (SAMSO) have announced that they have awarded a $5.5-million contract to North American Rockwell, Inc., Downey Division, for the fabrication of a new scientific spacecraft for launch in late 1973. The satellite will be an orbiting platform from which four instruments will obtain scientific data for several governmental agencies, writes Geoffrey Falworth. An Atlas F booster will launch the spacecraft into a near-polar, 550-km Earth orbit from Western Test Range, under the management of the Department of Defense Space Test Program.

Among the instruments will be a 3-kg optical intensity sensor built by University of Wyoming and sponsored by US Navy to measure the concentration of polluting aerosols in the stratosphere. The instrument consists of a photometer system to measure the intensity of solar illumination in near-infrared and blue wavelengths. The instrument's line-of-sight will be perpendicular to the plane of the satellite's orbit and as the spacecraft neared Earth's shadow, the instrument's line-of-sight to the Sun will pass first through the upper layers of the stratosphere and progress down into the lower layers as the satellite travels in orbit. During this time, measurements of solar intensity will be made at regular intervals for each observed wavelength. The same sets of measurements will be repeated as the satellite leaves eclipse and enters sunlight as the Sun line passes upward through the layers of the stratosphere. The data will enable scientists to map accurately the distribution of aerosols in the stratosphere and study their effects on atmospheric heating.

A second sensor, built by the MIT-Draper Laboratory for SAMSO will map in detail Earth's ultraviolet horizon; data from this experiment will be used by SAMSO engineers to investigate the possibilities of using Earth's ultraviolet limb as a reference point for horizon scanners.

A third set of instruments aboard the spacecraft will study the effects of Earth's ionosphere on the accuracy and resolution of radar systems in a Defense Nuclear Agency-sponsored study.

The fourth set of instruments, sponsored by U.S. Air Force Systems Command, will measure seasonal and geographic variations in Earth's background radiation and evaluate Earth sensor performance and techniques.

The Space Test Programme, managed by SAMSO for the Department of Defense, provides spaceflight opportunities to DOD-approved space research and operational space payloads which are not normally able to be launched on their own boosters; Space Test Programme payloads are launched on boosters flying non-related missions.

SOLID FUEL RAMJETS

The performance of a variety of fuels, binders, and oxidizers for use in solid fuel ramjets has been investigated for the Naval Weapons Center by United Technology Center. Tested under simulated flight conditions of Mach 2 at an altitude of 20,000 ft., several of the fuels have been selected for scale-up testing to evaluate as well as verify prior test data over a wider range of simulated speeds and altitudes. Criteria for evaluation will include specific impulse, density, and cost.

Dr. Bernard Iwanciow, UTC project manager, said that a solid ramjet would have to be travelling at Mach 1.5 or better before it could become efficient. At that point, air moving at supersonic speed relative to the vehicle, is captured by an inlet, then slowed down in a diffuser to increase its pressure. This pressurized air is then used to burn the solid fuel to produce thrust.

'Current interest in a solid-fueled ramjet – basically a 30 year old concept – is because it is potentially an economical engine for a supersonic vehicle,' Dr. Iwanciow commented. 'The density and heat release which can be obtained through the use of solid fuels permits the engines to be made very compact. In addition, elimination of the compressors and turbines using the ram air principle and elimination of a fuel system vastly simplify the engine with corresponding reduction in cost'.

MAKING ENZYME IN SPACE

Space scientists are looking into a claim by a leading American biophysicist Dr. Alexander Kolin that a life-saving enzyme, used to treat victims of pulmonary embolism – clots that block the flow of blood to the lungs – can be produced more effectively in space than on Earth.

At present the enzyme – urokinase – costs about $1,000 to treat one patient because it is extracted by a laborious process from human male urine which produces only one dose for 1,500 quarts of urine.

Dr. Kolin claims that he could make the enzyme far cheaper under weightless conditions in orbit. His method

involves making it from kidney cells of miscarried human fetuses. The machine he has developed, which would be installed in a manned spacecraft, separates the one 'active' kidney cell from 19 inactive cells using a moving electric field to transport cells of different density at different speeds.

After being separated in orbit the kidney cells would be placed in glass phials, frozen and returned to the ground for processing in a laboratory.

Dr. Kolin hopes to get the National Aeronautics and Space Administration to test his invention in the Apollo spacecraft to be flown in 1975 in the joint U.S./Soviet docking mission. Already groups of medical researchers and engineers are working on the project. They include Abbott Laboratories of Chicago and a leading aerospace company, the Convair Division of General Dynamics Corporation.

WOMAN DIRECTS SPACE LAUNCH

Among the some 200 American and Italian space experts involved in the successful launching off the east coast of Kenya of the US-built scientific satellite SAS-B on 16 Nov. 1972, was a woman who is project manager of the entire Small Astronomy Satellite (SAS) series, Marjorie R. Townsend of the United States. Like others witnessing the event, Mrs. Townsend 'was elated at the good launch', said a member of her staff at the Goddard Space Flight Center at Greenbelt, Maryland. The Goddard Center had been in frequent daily contact with the Italian-operated San Marco equatorial range, site of the SAS-B lift-off, about 3 miles off Kenya's coast near the city of Malindi.

As was the case with 2 other US-built scientific satellites previously launched from the San Marco facility – the X-ray satellite 'Uhuru' (Explorer 42) and the SAS-A (Explorer 45), sent aloft on 12 Dec. 1970, and 15 Nov. 1971, respectively – data collected from the 410 lb. SAS-B is sent to the Goddard Center for analysis.

SAS-B, designated Explorer 48 once it entered orbit, contains a gamma-ray telescope for detecting rare celestial gamma rays and determining their intensity, energy and direction of travel. Scientists believe such data may answer some fundamental questions about stars, galactic magnetic fields and cosmic rays. SAS-B's primary spaceflight tracking data station at Quito, Ecuador, was the first station in the NASA tracking-data network to pick up signals from the craft, indicating it had reached a 'good orbit'. SAS-B was launched by the 4-stage Scout rocket, NASA's smallest and lowest-cost orbital-launch vehicle. It was Scout's 26th consecutive success, a new record for NASA launch vehicles.

Mrs. Townsend has headed the SAS project since its inception in 1966. An electronics engineer, she has been with Goddard Space Flight Center since shortly after it opened in 1959. As project manager she is responsible for all aspects of the SAS operation – design, fabrication, testing launch, and integration of information from ground stations to craft and *vice versa*. As a staff member put it: 'She's the one who makes the decisions – like, do we hold? Do we do it this way or do we do it that way?

On her way to Kenya for the SAS-B launch, Mrs Townsend stopped in Rome to receive the decoration of Knight of the Italian Republic, bestowed upon her by the head of Italy's space centre at the University of Rome. The award was for her contributions to joint US-Italian space efforts.

JOINT FLIGHT TO MARS?

In the present age of the scientific and technical revolution, the peoples of the world must pool their efforts to solve global problems and enhance their power in the Universe, cosmonaut Vladimir Shatalov said in a press interview in Moscow on the 15th anniversary of the first Sputnik. Shatalov flew in Soyuz 8 and Soyuz 10.

As the tasks of space exploration become greater and the space programmes more complex and more costly, this co-operation becomes more pressing, Shatalov stressed, and he pointed out that a beginning had already been made with space co-operation with the socialist countries and France.

He said that he hoped that a manned flight to Mars, which would possibly be made before the end of the century, would be an international flight, and possibly it would be a Soviet-American one.

As a cosmonaut, he said he was particularly interested in the Soyuz-Apollo joint experiment envisaged in the Soviet-American agreement. A Soyuz spaceship manned by two cosmonauts would be launched first, then seven and a half hour later an Apollo spaceship manned by three astronauts would be launched from Cape Kennedy. Twentyfour hours after that Apollo would approach Soyuz and dock with it.

The system formed would be operated as a single spacecraft. In the course of two days the spacemen would move from one ship to the other, scientific and technical experiments would be made and there would be TV transmissions to Earth. On the third day the ships' would be undocked and land in their respective home areas.

Shatalov said that the main tasks of this experiment were to perfect the elements of the flight of spaceships launched from different cosmodromes and inter-action of crews with ground controls while carrying out the tasks set. It was necessary, he added, to study the expediency of a number of design decisions, in particular the module enabling spacemen to move from one ship to another, to study the specific features of operating the docked ships, and many other factors.

SHUTTLE SUPPORT CONTRACTS

North American Rockwell Corporation (NR) has issued subcontracts to Grumman Aerospace Corporation and McDonnell Douglas Corporation to provide specialised engineering services on the space shuttle orbiter programme.

NEXT MONTH

At the end of last year the Society opened a new line of enquiry by focussing attention on new teaching aids which may be expected to flow from the development of direct broadcasting satellites. A number of leading educationalists, both UK and continental European, gathered at Southampton University to examine the prospects. What they had to say will appear in *Spaceflight* next month. Other features in this issue will include: 'The Last Apollo – 2' by David Baker, and 'Modular Space Station Facilities' by P. J. Parker.

HIGH PERFORMANCE SOUNDING ROCKET

A new low-cost high performance sounding rocket, being developed by Bristol Aerojet Limited in conjunction with the Institute National de Tecnica Aerospacial of Spain, is to have its first flight trials early in 1974. Co-operating in the development of the rocket motors are the Rocket Propulsion Establishment and the Explosive Research and Development Establishment.

The two stage rocket – INTA 300 – is designed to lift a 50 kg payload to a height of 320 km with low dispersion, or 30 kg to 400 km. The system is expected to have wide appeal. The close attention which the designers have given to achieving low dispersion of a high-altitude rocket introduces the opportunity to launch from smaller ranges which will permit its use for a wide variety of tasks, including specific Earth resource studies.

Orders are now being accepted for delivery in 1974.

Rocket Design

Each rocket motor and the payload have a common diameter of 260 mm. The booster is a standard design already used in large quantities. The second stage has a new motor designed for exceptionally high performance in the trajectory. It combines low thrust with long burning time in order to limit kinetic heating of the skin of the vehicle.

Motor cases are made from helically welded high tensile, low tolerance strip. The propellent charges are made from case bonded, radial burning propellent with conventional conduits. Storage is possible to 5 years at temperatures between -15°C and +50°C. The stages are expendable.

Fins on the main vehicle are designed as a plastic – metal laminate with very closely controlled tolerances to obtain accurate roll rates.

Payload

A payload space of 35 litres (2140 in^3), not including telemetry bay, is available assuming the standard U18 telemetry unit is fitted. As designed for prototype flights the payload space comprises a cylinder 237 mm diameter, 535 mm long, topped by a cone of the same diameter x 500 mm long.

The minimum experimental package weight is 27 kg with a total nose weight forward of the motor of 36 kg. The maximum apogee obtainable at this payload weight is 400 km without aerials or 380 km with 465 type spike aerials.

INTA 300: Principal dimensions

Overall length	7272 mm	
Motor diameter	260 mm	
Max. fin span	1080 mm	
Payload volume *	40.1	(3998 cm^3)

INTA 300: Standard Performance for 85°QE

Payload weight *	44 kg
Apogee	327 km
Launch velocity	69 m/s
Max. axial acceleration	29 g
Max. spin rate	6 r.p.s.
Ranging	29.5 km/deg.
Wind effect	0.46 deg. per m/sec

** Includes Telemetry unit.*

A forward ejecting nose shell will be available for experimental payloads which need to be exposed in space. An attitude control system is being considered.

Telemetry and Tracking

A suitable PCM telemetry sender installation can also be made available. With U18 EMI telemetry, monitoring of 22 high speed channels and 23 low speed channels is possible. A power amplifier gives 5 watts output for good reception throughout the 320 km trajectory. A Doppler tracking system installation exists.

Launch System

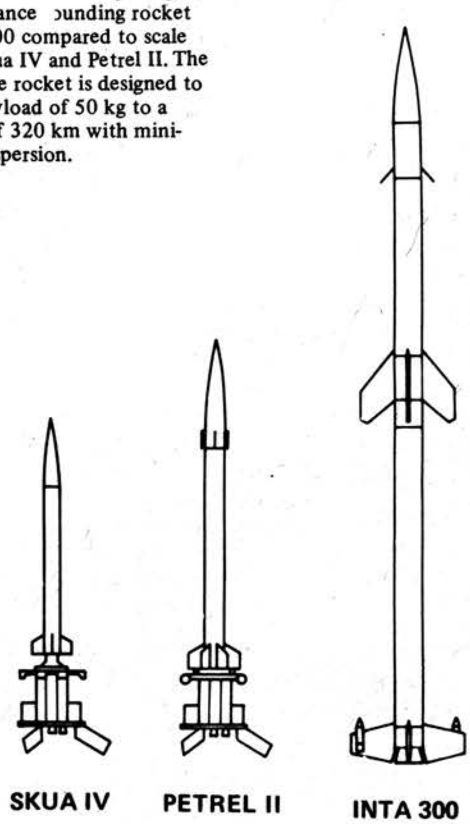
The rocket is launched from a special attachment to a Nike launcher. To minimise dispersion due to wind the rail can be designed to be 10 m long. With a shorter launcher, e.g., zero length Nike, the launch acceleration of the rocket (26g) is sufficient to give acceptable dispersion at ranges all over the world. Primarily designed to be acceptable for the Kiruna range, the UK range (Hebrides) being larger in area should be useable – the radius of the 99.99% probability impact circle for the current mean 1_{σ} ballistic wind error allowance of 4ft/sec. is 49.0 km.

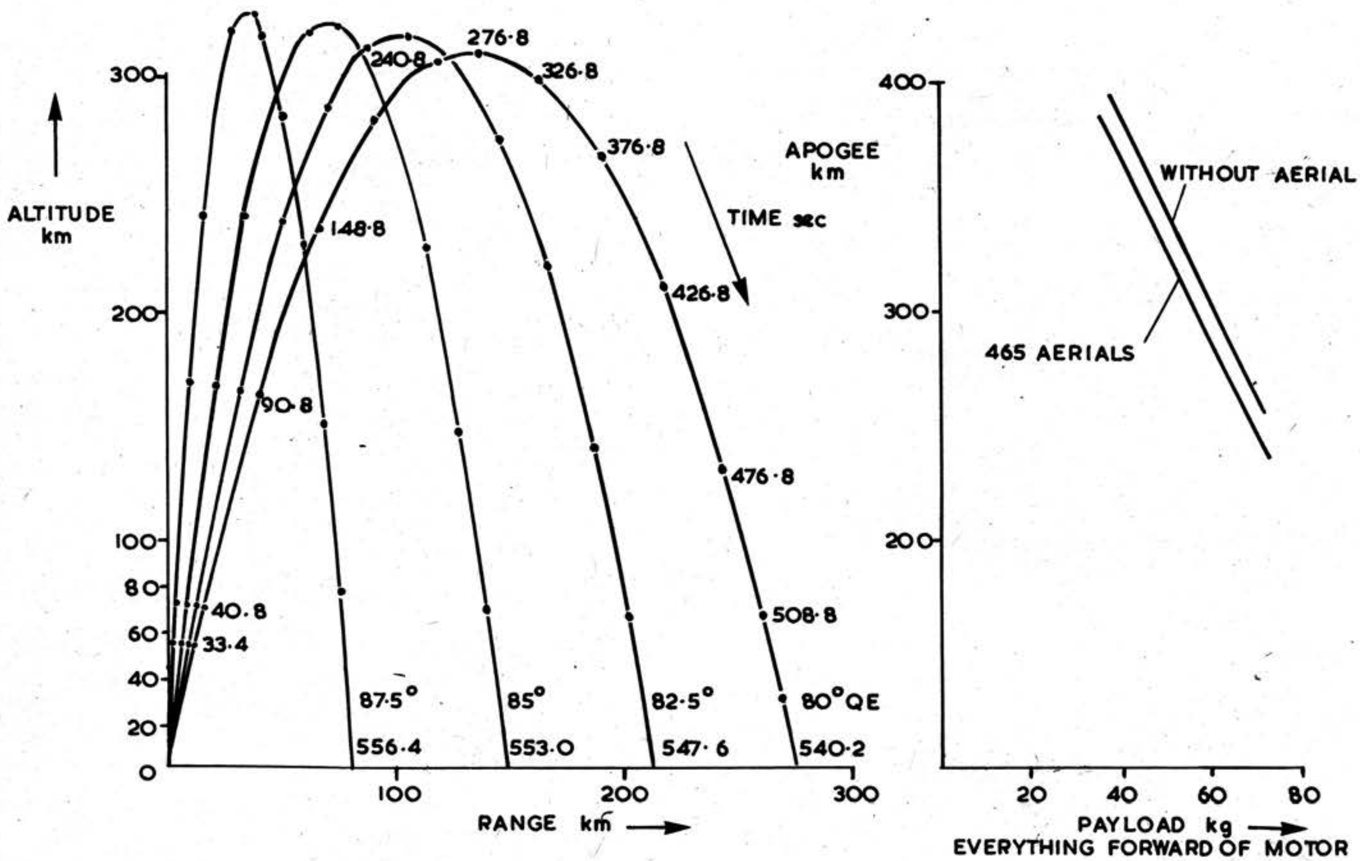
A spin-up system, utilising small rocket motors mounted at the tips of the boost fins,provides a rapid rotation on leaving the launch rail to reduce dispersion. A safety break-up system has been designed but will not normally be fitted.

Trajectories

Typical second stage trajectories are indicated on page 70. The boost will fall away from the rocket at 2.5 km altitude

The new Bristol Aerojet high-performance sounding rocket INTA 300 compared to scale with Skua IV and Petrel II. The two-stage rocket is designed to lift a payload of 50 kg to a height of 320 km with minimum dispersion.





INTA 300. Trajectories for varying Q.E. (465 aerials) for a 50 kg payload. *Right,* variation of apogee with payload weight Q.E. 85°.

Bristol Aerojet

and will impact at 500 - 600 m. forward of the launcher for 87°QE at 75 seconds from time of launch.

Dispersion

The exceptionally low dispersion is due to the large first stage boost. This assists radar acquisition and range safety. For 327 km apogees:

Ranging 9.2 km per degree per 100 km.
Angular 0.46 degrees per m/sec wind.

Propellent

The motors use plastic propellents which have been developed in the United Kingdom and have many advantageous features. These include exceptionally low cost, economical small quantity production and repressing for extending life by application of heat and pressure. The charge is chemically stable and can be stored and fired over temperature limits between -15°C and +50°C.

Safety

The ignition systems for the first and second stage motors and the spin-up motors are fully shielded against R.F. hazards. Arming systems are duplicated and the second stage is armed in flight, well clear of the launcher.

Packaging

Normally the motors will be delivered in airtight steel cases suitable for transportation by sea. Evacuated canisters can also be made available which would allow storage for up to 5 years without special buildings.

SUCCESS OF ARIEL 4

Ariel 4, Britain's second scientific satellite built by British Aircraft Corporation Electronic and Space Systems at Bristol, completed 12 months of service on 11 December 1972 thus achieving its design objective. Scientific experiments which functioned after launch continued to return good quality data to experimenters in England and to the United States experimenter at Iowa University.

The following is the text of a NASA statement which relates to a number of unauthorised items taken to the Moon, and commercial transactions – alleged to have taken place at the time of the Apollo 15 mission.

The Apollo 15 lunar exploration mission was launched on 26 July 1971, and returned to Earth on 7 Aug. 1971, after successful accomplishment of the scientific and technical objectvies. The first lunar roving vehicle was operated on the Moon to extend the range of exploration, some 81 kg (180 lb.) of lunar surface samples were returned for analysis, and a battery of very productive lunar surface and orbital experiments were conducted. The crew of Apollo 15 were Col. D Col. David R. Scott, mission commander, Lt.Col. Alfred M. Worden and Col. James B. Irwin.

Since the mission, a number of questions have been raised concerning the propriety of the crew's conduct, especially in relation to the disposition of personal souveniors and mementos. Careful investigation has established the main facts and has led to a determination by NASA that there were cases of violation of regulations, irregularities, and poor excercise of judgment by the crew; that some of the management communication lines within NASA were weak; and that certain administrative procedures were deficient.

Postal Covers

One issue has been that of postal covers carried on the mission by the crew. NASA has authorized astronauts to carry certain personal items on manned flights, known as 'Astronaut Preference Kits' (APK's). All such items must be listed and approved prior to launch, are intended for private use or as personal gifts after the flight, and may not be employed for commercial purposes or personal gain. Astronaut kits typically have included badges, jewelry, coins, medals, flags, stamps, postal covers, charms, currency, printed materials, pennants, and similar easily packed, light weight, and non-hazardous mementos. On Apollo 15, there was a total of 641 postal covers carried by the crew, of which 243 were listed and authorized before the flight and 398 were not.

Authorized Covers. The 243 listed and authorized covers include:

(a) Two US Postal Service Covers, one of which was publicly cancelled on the Moon by Scott at the request of the US Postal Service; the second cover, a backup, was not taken to the lunar surface. Both covers have been returned to the Postal Service.

(b) One Wright Brothers commemorative cover, dated 1928 and autographed by Orville Wright, which was carried by Worden for a friend and is currently in that friend's possession.

(c) One cover labelled 'Flown to the Moon' bearing a First Man on the Moon stamp and a Bliss Centennial 3-cent stamp, which was carried by Irwin for a personal friend of Richard Gordon's, former astronaut, and is currently in that friend's possession.

(d) Eight covers imprinted with a Shamrock and bearing the notation, 'This envelope flew to the Moon on Apollo 15 – Jim Irwin', which were carried by Irwin. Two have been given to and are retained by NASA employees and six remain in Irwin's possession.

(e) Eighty Seven Apollo 12 covers (initially thought to be 88) that did not fly on that mission and which were carried on Apollo 15 by Irwin for Mrs. Gordon. These are in the possession of Mrs. Gordon, a stamp collector.

(f) One hundred and forty four Apollo 15 covers which were carried by Worden. 100 of these were especially printed with a cachet showing 15 phases of the Moon and marked with the launch and recovery dates by F. Herrick Herrick, a philatelist and friend of Worden's, with the aid of Herrick's son. Herrick had advised the Apollo 15 crew to carry first-day covers and to then store them safely for some years, during which they would become valuable collector's items. On the *USS Okinawa*, the Apollo 15 recovery ship, the astronauts placed two 8-cent stamps purchased on board by Worden on each of these covers and they had the covers cancelled by the shipboard post office. The astronauts later autographed these covers while flying back from Hawaii to Houston. Sixteen covers were torn or damaged and were destroyed. Worden gave away 28 of these covers to friends. He then gave 40 to Herrick (28 for himself and 12 for Herrick's son) and entrusted the remaining 60 to Herrick for safekeeping. Herrick has stated that he personally sold 3 of his covers, has sent several to Europe for eventual sale, and has sold 10 more through a dealer on commission; Herick has realized some $7,175 thus far. To date, no information has been developed indicating that there were agreements or arrangements between Herrick and Worden whereby Worden was to have received anything of value from any sale of the covers by Herrick. Worden later requested Herrick to return the 60 covers entrusted to him; the returned covers have been impounded by NASA.

Unauthorized Covers. The 398 unauthorized covers (initially thought to number 400) are light-weight envelopes carrying as a cachet a replica of the official Apollo 15 patch overprinted with an Air Force wing and propeller emblem. They were part of a large order of cacheted covers paid for by a privately employed public relations man with a wide circle of friends among the NASA astronauts. These 398 were properly packaged for flight and carried on board Apollo 15 by Scott in a pocket of his space suit: each carried a 10-cent 'First Man on the Moon' stamp and had been cancelled at the Kennedy Space Center Post Office early on 26 July, 1971, the morning of the flight. These covers were not listed as being in Scott's preference kit; had they been so listed, they would probably have been routinely approved for inclusion in a preference kit as had the 243 authorized covers noted above. On the *USS Okinawa*, the Apollo 15 recovery ship, the astronauts purchased twin 8-cent stamps and affixed them to these covers. The covers were then cancelled and date-stamped (7 Aug. 1971) in the shipboard post office. The astronauts later autographed these covers while flying from Hawaii to Houston. On 31 Aug. 1971, 100 of these covers, already carrying the handwritten notation, 'Landed at Hadley, Moon 30 July 1971. Dave Scott, Jim Irwin', had the additional legend,

> 'This is to certify that this cover was onboard the Falcon at the Hadley-Apennine, Moon, July 30 – August 2, 1971'

typed on their backs and signed by a notary public. It was these covers that later came on to the commercial philately

market in Europe.

Investigation has established that Herman E. Sieger of Lorch, Germany, a major European stamp dealer, became acquainted with H. Walter Eiermann while on a visit to Cape Kennedy in 1970. Eiermann, a naturalized American citizen, had been privately employed for many years in the Cape Kennedy area and was well acquainted with many in the astronaut corps. In early 1971, Sieger concluded that special stamped envelopes carried on a lunar mission would have significant commercial value; he thereupon approached Eiermann as to the possibility of acquiring such covers.

In the meantime, Eiermann opened a $7,000 savings account in a German bank for each of the astronauts with their consent. In February 1972, the astronauts decided not to accept these monies and Scott took steps to assure that the funds were returned to Eiermann. Eiermann suggested as an alternative to the savings accounts, that each astronaut receive a commemorative stamp album for their families. This suggestion, initially accepted by the astronauts, was rejected in April 1972 after further consideration.

The remaining 298 covers have been impounded by NASA.

Unauthorised Timepieces

Another irregularity that has come to light in the investigation of Apollo 15 was that Scott had on board two timepieces (a wrist watch and stop watch) that were not part of the normal mission equipment. During the preflight training period, Scott had agreed to evaluate these timepieces for the manufacturer at the request of a friend. Thinking they might be useful, particularly for the possible emergency timing of a manually controlled propulsion manoeuvre, Scott carried them on the mission but without prior authorization. NASA has deliberately withheld the name of the manufacturer of the timepieces to avoid commercialization of this unauthorized action.

'Fallen Astronaut' Sculpture

The Apollo 15 crew desired to make a personal, private, symbolic gesture commemorating all deceased astronauts and cosmonauts; this desire was reinforced by the death the month before of three Soviet cosmonauts during the Soyuz 11 flight. Scott had met Paul Van Hoeydonck, a Belgian sculptor specializing in space themes, at a dinner party and had discussed the possibility of such a memorial. From that discussion came the Apollo 15 crew's decision to place on the Moon a small sculptured aluminium figure provided by Van Hoeydonck, together with a plaque listing the names of the deceased, as the memorial. The crew's clear understanding with Van Hoeydonck was that was to be no commercial or personal exploitation of this memorial.

In a post-mission press conference, the crew reported the memorial ceremony and, in keeping with their understanding, did not reveal the sculptor's name.

In November 1971 the Smithsonian Institution indicated a desire to display a replica of the memorial statue and plaque; the Apollo 15 crew agreed under the conditions that the display be in good taste and without publicity. Scott undertook to get the replicas for the museum.

In March 1972, Scott forwarded replicas of the plaque to the museum, in April, responding to Scott's request Van Hoeydonck presented the museum with a replica of the statuette. The replicas are currently on display there.

In May 1972, Scott learned that further replicas of the statuette might be offered for sale. He wrote Van Hoeydonck asking him to check on this rumour. In his response, Van Hoeydonck confirmed that replicas were intended for sale and indicated that he felt no constraints or restrictions in this matter. The Apollo 15 crew strongly disagree with this position, feeling that their solemn understanding with Van Hoeydonck prohibits any such commercialization.

Nine hundred and fifty replicas of the 'Fallen Astronaut' figurins signed by the sculptor have been advertised for sale by the Waddell Gallery of New York at a price of $750 apiece.

Specific Actions

In recognition of the apparent intent of the Apollo 15 crew to gain personally from the exercise of their astronaut privileges in the matter of the unauthorized postal covers, but considering as well their ultimate rejection of such personal gain, Scott, Worden and Irwin have been formally reprimanded. Their official Efficiency Reports as military officers reflect a formal finding of lack of judgment. These two actions result in severe career penalties. whether the astronauts remain in Federal service or not.

In addition, the Department of Justice is investigating whether any criminal statutes have been violated and also whether any civil action on behalf of the Goverment is warranted. The Department of Justice has requested that NASA issue no further statements on this matter until the Department has completed its review.

SATELLITE DIGEST — 55

A monthly listing of all known artificial satellites and spacecraft, compiled by Geoffrey Falworth. Information is based on that supplied by the Space Department of the Royal Aircraft Establishment, Farnborough, NASA, Satellite News and BIS sources. For information on the derivation of orbital parameters, abbreviations, etc., see July 1972 issue, p.262.

Continued from January issue, p.

Name, designation and catalogue number	Launch date, lifetime and descent date	Shape and weight (kg)	Size (m)	Perigee height (km)	Apogee height (km)	Orbital inclination (deg.)	Nodal period (min)	Launch centre, launch vehicle and payload/launch origin
Cosmos 513 1972-60A 6135	1972 Aug 2.35 12.86 days (R) 1972 Aug 15.21	Sphere-cylinder 4000?	5 long? 2.44 dia	203 174	320 312	64.97 64.97	89.73 89.36	Plesetsk USSR/USSR (1)
 1972-60D 6143	1972 Aug 2.35 18.30 days 1972 Aug 20.65	Sphere?	2 dia?	161	322	64.95	89.33	Plesetsk USSR/USSR (2)
Explorer 46 1972-61A 6142	1972 Aug 13.63 50 years	Irregular octagonal cylinder + 6 panels 175.09	3.20 long 0.50 dia	492	811	37.70	97.65	Wallops Station, Virginia, Scout C NASA/NASA (3)
Cosmos 514 1972-62A 6148	1972 Aug 16.64 1200 years	Cylinder + boom?	1.4 long? 2.0 dia?	958	975	82.97	104.43	Plesetsk USSR/USSR
Cosmos 515 1972-63A 6150	1972 Aug 18.42 12.76 days (R) 1972 Aug 31.18	Sphere-cylinder 4000?	5 long? 2.44 dia?	189	325	72.86	89.66	Plesetsk USSR/USSR
 1972-63D 6166	1972 Aug 18.42 16.82 days 1972 Sep 4.24	Sphere?	2 dia?	174	256	72.87	88.82	Plesetsk USSR/USSR (4)
Mu 4S-4 1972-64A 6152	1972 Aug 19.11 10 years	Octagonal cylinder + circular frame + boom 74.84	0.68 long 0.71 dia	245	6291	31.03	156.85	Kagoshima Space Center, Mu 4S Japan/Japan (5)
Oao 3 1972-65A 6153	1972 Aug 21.44 500 years	Octagonal cylinder + cylinder + 2 booms 2222.64	3.00 long 2.03 dia	736	744	35.01	99.49	ETR LC 36B Atlas Centaur NASA/NASA (6)
Centaur AC-22 1972-65B 6155	1972 Aug 21.44 200 years	Cylinder 2083.84	8.14 long 3.05 dia	695	780	35.02	99.44	ETR LC 36B Atlas Centaur NASA/NASA (7)
Cosmos 516 1972-66A 6154	1972 Aug 21.44 600 years	Cone-cylinder	6 long? 2 dia?	251 920	263 1030	64.98 64.82	89.64 104.57	Plesetsk USSR/USSR (8)
Cosmos 517 1972-67A 6168	1972 Aug 30.35 11.86 days (R) 1972 Sep 11.21	Sphere-cylinder 4000?	5 long? 2.44 dia	204	288	64.98	89.42	Plesetsk USSR/USSR

Supplementary Notes:

(1) Orbital data at 1972 Aug 3.5 and Aug 4.1.

(2) Capsule ejected from 1972-60A at 1972 Aug 14.

(3) MTS A, first Meteoroid Technology Satellite, acquires engineering and scientific data on meteoroid penetration rates, velocities and flux at orbital altitudes in support of studies of micrometeoroidal impact hazards to spacecraft by evaluating multi-sheet bumper configurations as meteoroid protection structure and obtaining further data on near-Earth meteoroidal and micrometeoroidal flux. Explorer 46, intentionally attached to the Scout C launch vehicle's fourth stage after orbital insertion, holds four deployable aft-facing solar cell arrays, solar cell panels mounted around the exterior of the fourth-stage motor and solar cell panels mounted around the spacecraft's octagonal upper structure for power supplies operating, through rechargeable batteries, onboard experimentation, ground-commanded science and engineering telemetry and tracking beacon operating at 136.320 MHz at 0.5 watt and continuously-sunlit solar cell-powered meteoroid bumper telemetry operating at 136.650 MHz at 0.075 watt and transmitting to NASA's Goddard Space Flight Center satellite tracking network for magnetic data tape recording. Onboard experimentation instrumentation measuring numbers, masses and velocities of meteoroidal particles at orbital altitudes includes four bumper panels deployed radially from the spacecraft's upper experiment section each panel being sectioned into twelve 3.20-metres long, 0.48-metre diameter panels each consisting of 0.0254-mm thick stainless steel bumper covers mounted 12.7 mm in front and on each side of 0.0508-mm thick stainless steel main panel structures by leaf springs allowing bumpers to be collapsed flat against the detector walls prior to deployment, each panel holding eight pressurised cell detectors measuring and telemetering to ground stations cell pressure losses caused by meteoroid bumper and main panel penetrations. At launch each of the twelve panels was rolled into a 0.48-metre long, 0.114-metre wide cylinder and, after spacecraft orbital insertion, deployed by ground commanded motorised boom system while 96 individual pressurised gas containers were activated to rigidise onboard pressure cell detectors. Explorer 46's central octagonal experimentation section adjacent to the bumper panel deployment system holds twelve 0.203-metre long, 0.203-metre diameter, 0.152-metre deep box-shaped meteoroidal velocity detectors mounted between detector panel deployment activators around the spacecraft's upper structure utilising thin-film, 8000 Angstroms-thick, polysulfene capacitors mounted on each

detector's outward face and 0.013-mm thick stainless steel sheet backed by a second capacitor on the rearward face. Meteoroidal particles penetrating the exterior detector activate an onboard timing mechanism which is subsequently deactivated if the particle also impacts the stainless steel detector sheet and second capacitor, thus providing meteoroidal particle flight times and energy data over accuratly-known distance between first and second detectors. Orbital altitude micrometeoroidal flux is determined by 64 capacitor sensors each charged electrically between 40 to 60 volts and each consisting of a thin sandwich of non-conducting silicon dioxide between an inner layer of conducting silicon substrate and an outer layer of conducting thin-film vapour-deposited aluminium, 32 detector s utilising 4000 Angstroms-thick aluminium detector film and 32 detectors using 10000 Angstroms-thick detector film. Micrometeoroidal penetration of a capacitor causes vaporisation and ionisation of small amounts of the particle at the penetration area causing momentary short circuits and capacitor discharges which allows subsequent current flow to be monitored and recorded for later transmission to ground stations: capacitors have an automatic-recharge capability thus permitting long-term repeated micrometeoroidal impact detection. Following launch by first operational Scout C four-stage launch vehicle utilising new solid-propellant Algol III first-stage motor into a nominal orbit, two of the four primary bumper experiment panels deployed nominally and by 1972 Aug 28 had detected three penetrations by micrometeoroidal particles and continues to operate satisfactorily but deployment failure of remaining two panels caused Explorer 46 to perform non-axial rotation exposing onboard telemetry system battery to excessive sunlight causing battery overheating. To preserve battery power and insure maximum data return from primary bumper experiment telemetry from Explorer 46's secondary meteoroidal velocity detector and micrometeoroidal flux detector experimentation, the latter having detected about 2000 micrometeoroidal particles between launch and 1972 Aug 28, was temporarily terminated.

(4) Capsule ejected from 1972-63A at 1972 Aug 29.

(5) Fourth Japanese satellite and second Japanese scientific payload orbited measures Earth's ionospheric phenomena including plasma waves, plasma density, electron density and temperature at orbital altitudes, cyclotron instabilities, electron beam analysis, electromagnetic waves in Earth's ionosphere and Earth's geomagnetic field strengths using a boom-mounted magnetometer located on top of the spacecraft aligned along Mu 4S-4's main axis. Science and engineering telemetry is transmitted in real-time to Japanese ground stations at 400.500 MHz at 45 milliwatts and onboard tracking beacon transmits continuously at 136.695 MHz at 90 milliwatts. Solar cell arrays covering the satellite's cylindrical exterior maintain nominal onboard power requirements and recharge nickel cadmium batteries used during nightside transits.

(6) OAO C, fourth Orbiting Astronomical Observatory spacecraft designed to observe celestial ultraviolet and X-ray sources from Earth orbit and third to attain orbit, studies hydrogen, oxygen, carbon, silicon and other common element interstellar absorption, investigates ultraviolet radiation emitted by early-type stars and studies celestial X-ray sources. Octagonal spacecraft main structure consists of an aluminium alloy central experimentation cylinder holding a 1.91-metres long experiment optics Sun baffle and jettisonable Sun baffle dust cover, experiment optics Sunshade actuator, solar cell array and inertia booms attachment and deployment mechanisms and associated pyrotechnic devices, associated internal electronics packages and data-handling systems mounted in 48 internal location bays inside the spacecraft's octagonal structure and an overall covering of aluminium oxide-coated aluminium which, together with insulation, thermally-activated louvres, circumferential heat pipes and electrical heaters provide passive and active thermal control. Spacecraft stabilisation and control system incorporates rate and position primary attitude sensor using gyro inertial reference unit augmenting four gimballed star-trackers mounted on Oao 3's octagonal structure and base including two forward-viewing gimballed star-trackers with associated inertial reference unit initiated in sequence, electrically-scanned star-tracker rate gyros measuring spacecraft tumbling rates, precision digital solar-aspect sensor and a bore-sighted star-tracker activating primary and secondary high- and low-thrust nitrogen gas-jet thrusters mounted on Oao 3's cylindrical structure for initial three-axis stabilisation, an intertial reference unit facilitating spacecraft attitude manoeuvres and a coarse momentum wheel for star-tracker control maintains Oao 3's attitude to within ± 0'.1, each star-tracker consisting of an 8.89-cm diameter reflecting telescope mounted on 2°-of-freedom gimbals, which split incoming, second-magnitude or brighter target star images, gimbal angles being compared to ground-computed command angles to provide error signals which are processed into analog voltages accelerating intertia wheels and driving torquer motors in gimbal axes, two star trackers providing backup attitude reference during guide-star occulation, spacecraft reorientation and in increases of overall spacecraft performance lifetime while additional stabilisation is provided by two spacecraft structure-mounted inertia booms. Power supplies are maintained by 107900 silicon solar cells providing 1800 watts depending on spacecraft orientation and solar panel temperature mounted on two single-sided solar cell arrays each holding two main and two auxiliary cell panels deployed after orbital insertion while three rechargable nickel cadmium batteries charged by solar panel arrays during dayside transits provide backup power supplies prior to solar cell panel activation and during transits through Earth's shadow, battery-charging being controlled by a pulse-width modulation control and regulation unit while a regulator-converter and a voltage-inverter supply power to onboard experimentation at ±28 volts dc, ±10 volts dc, ±18 volts dc and 36 volts, 400 Hz ac. Spacecraft operation commands are received from NASA's Rosman prime ground station by Oao 3's onboard computer system VHF terminal receiving and demodulating digital commands and capable of handling 16000 18-bit words and storing 1024 ground commands allowing automatic operation between daily command-reception transits within Rosman audibility range. One-year nominal active lifetime digital spacecraft experiment data telemetry and spacecraft status data is transmitted on command at 136.260 MHz at 2 watts through a solar panel-mounted VHF narrow-band slot antenna and UHF wideband antennae and at 400.550 MHz at 10 watts to NASA's Space Tracking and Data Acquisition Network stations at Rosman, Quito and Santiago operated by Goddard SFC while ground-commanded, VHF low-power carrier-wave tracking beacon transmits continuously at 136.440 MHz at 0.16 watt. Onboard data processing system provides spacecraft timing for experiment data and command storage and spacecraft, experiment and instrumentation command execution and spacecraft status determination throughout the mission. Onboard experimentation includes Princeton University's ultraviolet astronomy experiment package consisting of a 450-kg, 3.05-metres long, 1.00-metres diameter cylindrical f/3, 16-metres effective focal length Cassegrain telescope system using an 82-cm, 47-kg, fused-silica rib-assembled primary mirror held against three quartz rods for mirror thermal control, viewing initially 47 young, hot, early-type stars to 7th magnitude at ultraviolet wavelengths between 930 and 3000 Angstroms in studies of abundance and temperature distribution of interstellar gas and stellar atmospheric structure during about 90% of Oao 3's scheduled observation periods. Primary mirror reflects ultraviolet radiation to internal 10-cm diameter secondary mirror which then reflects radiation through an ultraviolet spectrometer system comprising a narrow 0°.3, optical train-located entrance slit and concave grating and thence to a Rowland circle assembly surmounted by two movable scanning carriage arms each having one photomultiplier sensitive to a 1600- to 3200 Angstroms first-order spectrum, and a photomultiplier operating between 800 and 1600 Angstroms in second-order, examination of specific stellar ultraviolet spectral lines being performed by narrow exit-slit carriage providing 0.1-Angstroms resolution at first-order and 0.05-Angstrom resolution in second-order pre-programmed to scan repetitively and retrace over any pre-selected 0.7-Angstrom first-order interval or 0.35-Angstrom second-order interval, while second carriage's one-direction stepping motion each 16 sec. permits first- and second-order resolutions of 0.4-Angstroms and 0.2 Angstroms respectively. About 50% of stellar emission focussed on Princeton experiment package's main telescope system into the spectrometer's entrance slit is reflected into the telescope system's fine control guidance optics consisting of optical train-mounted photomultiplier, rotating mirror, second-field lens, roof prism and first-field lens, having a

Continued on page 80]

SOCIETY NEWS

23rd IAF Congress

A considerably fatter UK delegation returned from the 23rd IAF Congress in Vienna held from 8-14 Oct.1972, the endless coffee and creamy cakes having wrought havoc on even the most spartan frames.

The theme of the Congress was 'Space for World Development'. By Tuesday, some 650 participants had registered, the largest number (150 in each case) being from the Federal Republic of Germany and the USA. Over 170 representatives of the press also applied for accreditation.

Preparations for the Congress started a year before, immediately after the Brussels Congress. A staff of 10 had been employed, on a full-time basis, ever since, making use of the network planning technique. Some 25 assistants were actually at work at the Neue Hofburg, the Congress venue, during the actual event.

The Hofburg, the former Imperial Palace, has been adapted for congress use by the installation of interpreters' booths, a bar and coffee room, a press room and other facilities. Some of the utility fittings contrasted strangely with the huge glittering chandeliers, ornate ceilings and columnes of the palace. The numerous technical sessions on Space Transportation, Spacecraft Design, Materials and Structures, Fluid Mechanics, Propulsion, Astrodynamics, Materials Processing at Zero Gravity, and Bioastronautics were held simultaneously in different halls and dispersed the participants. Concurrently there were also symposia on Space Rescue, the Lunar International Laboratory, Nuclear Power in Space Propulsion, Space Law, the History of Astronautics, and Communications with Extra-terrestrial Intelligences, as well as an IAF Students Conference.

So many things went on simultaneously that, unless one had a very narrow interest in one subject, it was impossible to hear many of the interesting papers and discussions. An inadequate organisation of the distribution and copying of papers also made it difficult to obtain copies of those papers which one had perforce to miss.

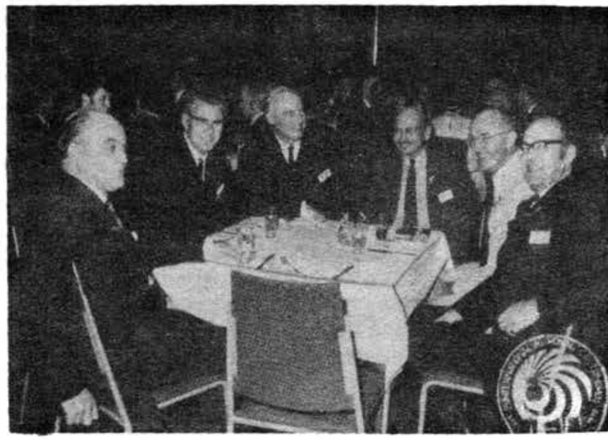
Opening Addresses

In a message to delegates at the Congress, United Nations Secretary General Kurt Waldheim called attention of Member States to the benefits of applied space research. Speaking in the Congress hall in the Hofburg on behalf of the Secretary General, Marvin W. Robinson recalled that the General Assembly had endorsed the formation of a Working Group on Remote Sensing of the Earth by Satellites.

The theme of the Vienna Congress was referred to by all speakers at the opening session on Monday morning. The President of Austria, Dr. Franz Jonas, opened the Congress in the presence of 1500 participants. He stressed the important implications of space technology, indicating that no other technological field has influenced the life of man stronger than space technology and space research, and spoke of the awakening interest of his country in space questions, an interest which is reflected primarily in a broadening of information activities.

The President of the IAF, Prof. Andre Jaumotte, recalled future European activities in this field and the urgent need to arrive at a solution to Europe's problems in space research.

The Fourth IAF Invited Lecture delivered by H. Guyford Stever, Director of the National Science Foundation in Washington, D.C., underlined the impact of space activities on world development. At the present stage, when attention is turning increasingly from pure research to application, it is time to invite all nations to take part in space work and to share in its benefits. The big task of humanity from now on will be to determine the aims which world development should pursue, and in doing so to give social considerations first place. Mankind's social evolution is more important than the mere introduction of technical innovations. Space is for the whole of mankind and not just for the big space nations which have so far done the pioneering work.



Relaxing at the Reception put on in the Austrian Parliament Building are (*left to right*) Nigel Hoare, Fred Barrow, Len Carter, Mitch Sharpe, John Neubauer and Cyril Horsford.

Dr. Wernher von Braun, looking younger than his years, gave a well attended public lecture in which he first pictured 'Spaceship Earth' flying towards a global catastrophe, though he finished on a more optimistic note.

Press Conference

Present at the Press Conference on October 10, were the two Soviet Cosmonauts Kubassov and Filipczenko, Dr. Wernher von Braun, Dr. Sedov, and Dr. Krafft Ehricke.

In relation to the Apollo-Soyuz Test Programme (ASTP) of the USA and the Soviet Union, all stressed the difficulties arising from the differences in atmospheric composition and pressure systems used. Soyuz spacecrafts use air at normal atmospheric pressure whereas the Apollo crafts provide pure oxygen at 1/3rd atmospheric pressure to their crews. For the joint programme which is to take place in 1975, special docking modules and air locks will be required to enable US astronauts to enter the Soviet spacecraft and *vice versa.* Dr. von Braun pointed out that the transition from lower to higher pressure, i.e., from Apollo to Soyuz is easy to make, whereas the Soviet cosmonauts will have to spend about 2 hours in the air lock. Soviet participants stressed the fact that their system, although it makes the spacecraft heavier, provides more natural and thus better working conditions for the cosmonauts and also lessens the fire hazard.

For the joint test programme in 1975 a Soyuz and an Apollo spacecraft are to rendezvous, perform a docking manoeuvre and allowing the occupants to visit both spacecraft during an experimental period. After this the spacecraft are expected to return to their respective countries.

When asked why the Soviet Union has not accepted an invitation for a joint programme at an earlier date, Dr. Sedov

explained that among several other reasons the political situation played an important part. Now that the situation is favourable the Soviet Union is happy to extend the co-operation which exists already for meteorological purposes.

Both the Americans and the Russians said that it is not yet known how long a human being can exist and perform work under zero gravity conditions in outer space. The longest period so far was performed by Soyuz 11 with 24 days. Mr. Kubassov said that the experiments will be gradually extended. Dr. von Braun referred to several experiments carried out in the United States which give details on human reactions regarding this phenomenon. Space flight periods up to 56 days are planned for the Skylab, but will only be carried out after the 28 day flight has proved to be successful.

Referring to the problems with space suits both cosmonauts said that different suits are used in and outside of the spacecraft and that there exist also special suits,for visiting other spacecraft with a different pressure, but it has not yet been decided which one will be used. They also said that no landing of Soviet cosmonauts on the Moon had been planned for the near future, since pilotless flights to Venus as well as to the Moon are being stressed.

Soviet Participation

The Soviet papers on life support systems and other subjects in bioastronautics were of great interest, particularly one which postulated that there was no longer any need for anti-coagulents for prolonged implantation of catheters in the cardiovascular system. C. A. Berry's (NASA, Washington) announced plans for 56 days stay of astronauts in space met with considerable scepticism.

There were interesting Soviet papers in the Fluid Mechanics and Astrodynamics sections, but the Application Satellite section suffered through the absence of Kondrat'yev and other Soviet contributors.

L. A. Kvasnikov's papers on 'Topaz' and other actual or potential energy sources for space use surveyed Soviet work in this field.

Throughout the Congress there was much talk of the planned USA/USSR co-operation in space and much display of friendliness between von Braun, Academician L. I. Sedov, who led the Soviet delegation and the two Soviet cosmonauts: Valery Kubasov, a civilian who had performed the welding experiment in space, and Anatoly Filipchenko who was in uniform. These friendly relations were particularly noticeable at the press conference when von Braun and the Russians tossed the journalists' questions to each other.

Space Law Colloquim

Some 32 papers were read at the 15th Colloquim on the Law of Outer Space, held at the same time as the Congress, and was well attended by lawyers from many countries. Topics discussed included legal problems arising from the use of Earth Resources satellites, and the question of an obligation to use the knowledge gained for the benefit of all states, particularly the state in whose territory resources are discovered. Broadcasting and telecommunication problems were also considered, as some aspects of this new field are controversial on political grounds.

The new Treaty on Liability for damage caused by space objects, which was signed at the UN in March 1972, was generally welcomed as being a valuable addition to space law, particularly for the benefit of the smaller countries, and Professor Zemanek, the Chairman of the Colloquim, said that progress was being made at the UN on the drafting of a new Treaty on the use of the Moon, proposed by the Soviet Union.

Legal problems arising from the projected Space Shuttle were also touched on by one speaker, and M. Bourely, the legal adviser of ELDO, said that the results of the 1970 European Space Conference were disappointing, and that the US has now placed a deadline for a decision by Europe as to whether to participate in the Shuttle programme. He urged European co-operation and said that the decision as to Europe's part in space projects is a political one.

History of Astronautics Symposium

The 6th Symposium of the International Academy of Astronautics presented a series of interesting papers on the rise of rocket technology, and how it was applied to space developments.

In his introduction to the Symposium on contributions to the history of rocketry and astronautics, Chairman Dr. E. M. Emme (NASA historian, USA) pointed to the velocity of change in space science and technology since the launch of Sputnik 1 in October 1957: 57 men have already flown in space, 10 men have already walked upon the lunar surface while 22 men have flown around the Moon. Two men (J. Lovell and S. Young) have made 2 voyages to the Moon and 2 Earth-orbital flights) – and suggested that posterity required a full accounting of how all this came about and who, what and where the story of astronauts evolved from the beginning.

Papers on the origin of astronautics in Hungary and Switzerland and Poland were presented by I. G. Nagy, A. Waldes and M. Subotourcz respectively. Three papers by Soviet authors were presented:–

T. M. Mel' Kurrove's on the early works of *Astronautic Pioneers*, an analysis of the rockets of F. A. Tsander by L. S. Dushkin and Ye. K. Moskkin, and the theoretical developments of ramjet engines by I.A. Merkalov (all Soviet authors are members of the Academy of Sciences, USSR).

Four memoir papers presenting personal and hence new information and viewpoints on astronautical history appeared as follows:

German Development of A-4 Guidance (E. A. Steinhoff)
The Viking Rocket Programme (M.W. Rosen)
Countdown to Space, 1945-50 (Prof. W. Pickering)
From Wallops Island to Mercury, 1944-50 (Dr.R.R.Gilruth)

Cost Reductions in Space Operations

Dale Myer's (NASA,Washington) two papers on the Space Shuttle, one of them a public lecture, were clear and

interesting, but they, and his subsequent press conference statements, dashed the hopes of European participation in the shuttle programme. These and other US papers were permeated with expressed awareness of high costs and inadequate funding of desirable space programmes.

This was also reflected by the fact that both sessions on 'Cost Reduction of Space Operations' were well attended, considerably more so than the first meeting on this theme held in Brussels last year.

Next Congress

The 24th IAF Congress will be held in Baku, Azerbaijan, in the USSR, during the period 8-15 October 1973.

A Note on the IAF

The International Astronautical Federation (IAF) is a nongovernmental association of national societies. Founded in 1950 with 11 members, it has today 57 members in 36 countries. The combined memberships of its member societies totals nearly 73,000 – over half of these (41,000) are members of the AIAA. The BIS is 5th in order of membership size.

The aims of the IAF are to foster the development of astronautics for peaceful purposes, to encourage the widespread dissemination of technical information, to stimulate public interest in space flight through the major media of mass communications, to encourage astronautical research, to convoke congresses and scientific meetings and to co-operate with other organizations in work related to all aspects of astronautics and the peaceful uses of outer space.

In 1960 the IAF created the International Academy of Astronautics (IAA) and the International Institute of Space Law (IISL), which co-operate closely with the IAF although they function autonomously.

1972/3 Council and Committees

The Scrutineers (Messrs. Hempsell & Tilbrook) reported that a total of 508 ballot papers were received up to 30 Sep. 1972, of which three were spoiled.

The number of votes cast for each candidate was as follows:

Professor G. V. Groves	–	409
G. V. E. Thompson	–	347
Dr. C. J. Brookes	–	337
Dr. W. F. Hilton	–	288
Dr. L. R. Shepherd	–	236
D. S. Carton	–	227
Dr. J. A. Cade	–	148

Accordingly, the first four named were declared elected to the Council.

At the first Meeting of the Council following this result, Professor G. V. Groves was re-elected President, with Mr. G. V. E. Thompson and Dr. W. F. Hilton as Vice Presidents, all for a 3rd term.

The composition of the Standing Committees for 1972/3 was fixed as follows:

1. *Finance & General Purposes* (concerned not only with the Society's financial affairs but also with all other matters which do not fall into any other 'slots').
   Professor G. V. Groves (*Chairman*)
   L. J. Carter — Dr. L. R. Shepherd
   K. W. Gatland — G. V. E. Thompson
   Dr. W. R. Maxwell

2. *Honours & Awards Committee* (To identify work worthy of recognition, including 'vetting' material for the Golovine Award, and to work closely with the Programme Committee.
   Professor G. V. Groves (*Chairman*)
   L. J. Carter — Dr. L. R. Shepherd
   Dr. C. J. Brookes — Dr. N. Simmons
   Dr. W. R. Maxwell — C. R. Turner

3. *Membership Committee* (To process applications for Membership and also to deal with matters of Membership promotion).
   Professor G. V. Groves (*Chairman*)
   L. J. Carter — G. V. E. Thompson
   Dr. N. Simmons — C. R. Turner
   (with power to co-opt.)

4. *Programme Committee (An ad hoc Committee* to undertake detailed arrangements for the Society's programme of Meetings and other activities).
   Professor G. V. Groves (*Chairman*)
   Dr. C. J. Brookes — Dr. R. C. Parkinson
   L. J. Carter — Dr. L. R. Shepherd
   K. W. Gatland — Dr. N. Simmons
   Dr. W. F. Hilton — C. R. Turner
   (with power to co-opt.)

5. *Publications Committee* (concerned not only with the monthly appearance of both magazines but also with other publications and matters of policy).
   Dr. W. R. Maxwell (*Chairman*)
   L. J. Carter — Professor G. V. Groves
   K. W. Gatland — Dr. L. R. Shepherd
   G. V. E. Thompson

Dr. L. R. Shepherd was also co-opted to the Council to serve until the next Annual General Meeting.

CORRESPONDENCE

Water and Life

Sir, There are some good and significant points made in the article 'Limitations of Terrestrial Life' by Dr. P. Molton (*Spaceflight*, January 1973) about the way a cell system could be modified in order to become adapted to very extreme environmental conditions. However, I feel that despite this, the author has allowed his arguments and deductions to be clouded by basing them on very conventional and fundamentally morphological concepts about 'life processes'. I agree that it is a matter of imaginative insight, to a large extent, as to what kind of 'exotic' systems we might be able to propose for the population of distant planets, etc. On the other hand, there is not, I would maintain, all that much doubt as to the essential features of *terrestrial* living systems.

What is becoming increasingly clear is that all living systems on Earth are essentially cellular (viruses are very special!), and the cell, as an energy exchanging unit, is powered by enzymes, the whole constituting an 'open' thermodynamic system. The irreversible reactions of that system are driven by an entropy flow, which is maintained by two factors: the flow of heat out of the cell, and the redistribution of water between bound and 'free' forms which goes with it. The essential corrollary of all this seems to me to be that actively functioning terrestrial systems can only exist in the presence of liquid water. The distribution of such systems in the universe must, on this basis, match the distribution of liquid water; the superposition of the physical conditions on other planets on the phase diagram of water gives the necessary information!

The only real problem lies in how well we know the conditions. It is also true, therefore, that the invention of new liquid milieus inside a notional terrestrial cell (e.g. glycerol, liquid ammonia, etc.) will not do in thermodynamic terms, if we are talking about *active* systems and not just surviving ones.

(Prof.) G. BELYAVIN

(*Dr. Molton replies:*

I agree entirely with the definition of terrestrial life excluding viruses, being cellular, powered by enzymes, and constituting an 'open' thermodynamic system. I never suggested otherwise. I also agree with the statement that active terrestrial systems can only function in the presence of liquid water – they wouldn't be terrestrial otherwise. I do not suggest replacing water with other solvents. Nor do I believe that a partial replacement of water by say, glycerol, will do, since in changing the properties of one enzyme system, you start a cascade which results in changing all of them, thus almost certainly killing the cell.

Terrestrial systems can therefore only exist where there is water. But, simply to superimpose the phase diagram for water on the known conditions of a given planet in order to determine the possibility of there being terrestrial life there is surely inappropriate. It presupposes the actual existence of water. True, if water could not exist in the liquid state anywhere on a planet, then, terrestrial life is ruled out. There are planets like Mars and Venus where liquid water could exist, but we don't yet know how much.

To apply thermodynamic arguments to a particular enzyme reaction taking place in non-standard conditions requires knowledge of several parameters. These are such things as free energy of the reaction, activation energy, concentrations of reactants at the enzyme (not in the solution around it), etc. And then the answer can be wrong because the system may be in non-equilibrium conditions. Then apply the argument to every state and reaction of a cell, integrate them all together, and you have an answer.

I think that the empirical approach (try-it-and-see) may be useful here. If I get any free time, I intend to try a few experiments on bacterial adaptation to adverse conditions. We already have results for one such experiment, but they are so controversial that we shall have to repeat the experiments before we can risk publishing them.)

Space Terminology Again

Sir, I regret I cannot agree with Mr Bell (*Spaceflight*, October 1972, p.399). Firstly, 'Earth Orbit' is indeed incorrect too; the correct term is geocentric orbit.

Secondly: I agree that everyone will understand that Mariner IV is the same space probe as Mariner 4, but is that a sufficient reason to use both numerotation systems? Will Mr. Bell write Cosmos CCCLXXXVIII or simply 388? It is so wise to write, for example, Nimbus 2 and, on the next line, Tiros III, as some authors do?

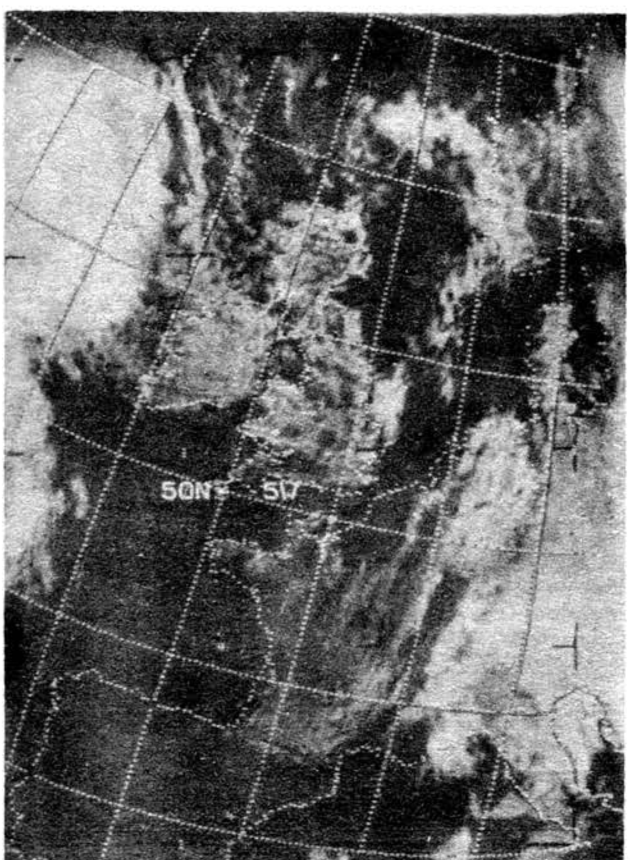
Mr. Bell asks since when we have been forbidden to use Roman numerals. The answer is: since 1 May 1969. On that date, NASA issued a special note, stating that for artificial satellites and space probes *Arabic* numerals must be used.

Thirdly, we must say 'aposelene' instead of 'apolune', since astronomers since more than a century say 'selenographic' and 'selenocentric', not lunographic nor lunocentric.

In replying to Mr. Croot, may I say that the *orbit* of a planet or of a satellite is its *path* around the central body, while the term 'revolution' is used for the motion along this path. Thus, astronomers say that Jupiter makes 8 *revolutions* (not 8 orbits!) on its *orbit* around the Sun. Why make things complicated and speak another language for the artificial satellites?

Astronomy is the oldest science, while spaceflight began less than 20 years ago. Therefore the spaceflight engineers should follow the astronomical pratice.

JEAN MEEUS



ESSA-9, Pass 5379, 11 July 1972.

Britain from Orbit

Sir, I have yet to see, anywhere, a photograph of the British Isles taken from Earth orbit. I mean the British Isles with identifiable features and not just a cloud mass.

Have you any such photographs on your files and if so, can you publish one in *Spaceflight?*

R. D. MILLER

*(We asked the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, to supply a suitable photograph. The picture (*left*) was taken by the ESSA-9 satellite on 11 July 1972 – Ed.)*

Pioneer 10

Sir, In Satellite Digest - 50 (*Spaceflight*, September 1972, p. 345) Pioneer 10 is quoted as being on a heliocentric orbit. In fact, it is pursuing an *Interstellar Trajectory.* (KSC Unmanned Launch Operations, Press Release 'Pioneer F'); it is due to be close to Aldebaran (*α Tauri*) 53 light years away some mere 1.7 millions of years hence. I have listed Pioneer 10 as star system #1639 in my star catalogue, with a crude calculation of its proper motion.

F. G. GRAHAM

'Challenge of the Stars'

In my recent review of this book, my phrasing implied that all the text was by Patrick Moore. This is not correct, David Hardy was also the co-author and wrote much of the accompanying descriptions to his paintings.

ANTHONY T. LAWTON

Satellite Digest 55*/Continued from page 74/*

0".1 spacecraft stabilisation capability when observing a 7th-magnitude object. Internal calibration source, consisting of one of two ground-command iron-neon discharge sources illuminating a small mirror adjacent to the spectrometer's internal entrance slit, allows in-orbit confirmation of ultraviolet wavelength relationship and moveable carriage arm location during observation. Photon count output, proportional to ultraviolet radiation intensity at specific wavelengths, is converted to digital data by experiment-associated electronics and telemetered through Oao 3's science data handling subsystem to ground stations. Tubular cylindrical Sun baffle extending from the spacecraft's upper section permits operation of Princeton University's experiment package during sunlit transits. University College, London, stellar X-ray telescope system studies and locates to within ±1' of arc stellar X-ray sources between 1 and 60 Angstroms and interstellar X-ray absorption using equipment mounted in Oao 3's main structure upper experiment bay consisting of three co-aligned grazing incidence telescope systems measuring X-radiation at wave lengths between 3 and 9 Angstroms 8 and 18 Angstroms and 20 and 60 Angstroms, supplemented by a coarse collimated 30' of arc field-of-view proportional counter observing a larger-area sky background between 1 and 3 Angstroms coupled to gas proportional counters and an open-tube channel multiplier; experiment package also contains optical star-tracker system detecting deviations of up to 4' of arc between experimentation's optical axis and the spacecraft's axis resulting from in-orbit experimentation thermal distortion and vibrational relaxations in experimental equipment. Operating during about 10% of Oao 3's scheduled observing periods, experiment, first non-US experiment flown on an Orbiting Astronomical Observatory, acquires data which is subsequently processed in digital form by onboard data handling subsystem and thence transmitted to ground stations. Launch was nominal and after separation from the Atlas D first stage Centaur fired for about 7.5 min. about 244 sec. after launch placing the Centaur AC-22/Oao 3 combination in a near-circular Earth orbit following which explosive bolts attached to the spacecraft adapter band fired and compressed springs separated Oao 3 from the rocket stage at about 1 metre per sec. Five minutes after spacecraft separation Centaur AC-22's attitude control thrusters re-oriented the vehicle as 223-newton thrust hydrogen peroxide vernier engines settled propellants prior to venting of excess liquid hydrogen and liquid oxygen to space to provide thrust to place Centaur AC-22 in a differing orbit from Oao 3. Initial eight-days spacecraft systems test period commenced during the spacecraft's first 6 orbits in which Oao 3 was controlled by its onboard initial flight command memory, onboard instrumentation and electronics were systematically operated on ground command, initial engineering telemetry was analysed by ground-based operational personnel to evaluate attitude control and thermal systems performance to ensure nominal power supply systems operation, power levels within the spacecraft were brought up to nominal operational values and experiment optics' Sun baffle dust cover (1972-65C) was jettisoned. During orbits 7 through 92 various spacecraft control modes and operational capabilities were exercised, high-voltage power system was activated and thermal equilibrium and high-power system optimisation was achieved. Engineering checkout was completed by 1972 Aug 29.45, only anomaly being a telescope sensor which relayed apparently incorrect data to Earth. Uncorrected drift rate after orbital insertion was less than 1" each 75 days while spacecraft pointing accuracy was within ±0".03 and basic spacecraft stability during non-observational periods was 2" per hour. Formal operation of Oao 3 commenced during 1972 Aug 29 with a four-days observational series of the young ultraviolet star zeta Ophiuchi, following which University College, London, X-ray telescope experiment was operated.

(7) 28th Atlas Centaur orbital mission and 24th successful Centaur flight.

(8) 1972-66A attached to Cosmos 516 rocket (1972-66B) and Cosmos 516 platform (1972-66C) until orbit change at about 1972 Sep 21.93. Orbital data at 1972 Sep 1.5 and Oct 1.7.

Decays:

Cosmos 440, 1971-79A, decayed 1972 Oct 29, lifetime 401 days.
Cosmos 487, 1972-33A, decayed 1972 Sep 24.09, lifetime 155.59 days.
Intercosmos 7, 1972-47A, decayed 1972 Oct 5.65, lifetime 97.40 days.
1972-52A decayed 1972 Sep 13, lifetime 68 days (R).

Amendments:

Molniya 1Q, 1970-77A, lifetime is 2.5 years.
1971-05A, lifetime is 19 days (R).
1971-33A, lifetime is 21 days (R).
1971-67C, weight is 362.88.
1971-67D, lifetime is 43.59 days, descent date is 1971 Sep 19.60, weight is 61.24.
1971-67E, weight is 37.38.
Venus 8, 1971-21A, weight is 495.
1972-36D, lifetime is 20.35 days, descent date is 1972 Jun 6.78.
1972-44D, inclination is 65.41, period is 88.98.
Prognoz 2, 1972-46A, second orbit perigee is 517, apogee is 201804, inclination is 65.3, period is 5849.2, add to Supplementary Note (7): Orbital data at 1972 Jun 29.5 and Aug 1.0.
Cosmos 200, 1968-06A, lifetime is 5.5 years.
Operations 8285, 1969-65A, lifetime is 4 years.
Cosmos 481, 1972-20A, lifetime is 161.39 days, descent date is 1972 Sep 2.84.

TAILPIECE

Then there was the story about the Italian technician who shaved off his handlebar moustache to eliminate interference with WREBUS propagation following a series of unsuccessful launch attempts for F6/1,A – due to WREBUS tracking problems!

and at home........

The Director of a certain Establishment was showing round a party of visiting politicians. Included in the party was a garrulous lady who checked and probed and queried everything. Eventually, arriving at the safety barrier to watch a static motor firing, the lady prodded the barrier and demanded to know why it was in that particular place, i.e., why it was safe on one side yet unsafe on the other just a foot or so away.

At that moment, the static test began. Unfortunately, everything did not go well: there was a violent explosion and parts of the erstwhile motor came sailing through the air. A large part landed with a plonk on the far side of the safety barrier, near the feet of the garrulous lady.

At that point, the Director pulled himself up to his full height and said 'Madam, everything is worked out *exactly!*'

Not long ago the B.I.S. received a letter from an Indian gentleman who claimed to have met the materialised person of Albert Einstein in India near a railway station. Einstein, he said, has told him that he must immediately inform the world that his Theory of Relativity was false. He implored the Indian first to contact the Pope; otherwise 'Time-Life'. 'The Daily Express', or Ken Gatland (in that order!).

The Modern Touch ....

There was the sad story from Australia. The Earth Resources Rocket had flown well – all too well it seems, for the local Tax Inspector had been studying the pictures, which disclosed the existence of a farm on which no taxes had been paid...........

THE BRITISH INTERPLANETARY SOCIETY

LIMITED (by guarantee)

12 Bessborough Gardens London SW1V 2JJ (Tel. 01-828 9371)

STRUCTURES OF SPACE VEHICLES AND SPACECRAFT

To be held in the Architecture Lecture Theatre, University College, Gower Street, London, W.C.1.

3rd–4th April 1973

PRELIMINARY LIST OF PAPERS*

Mechanical and Structural Aspects of ESRO IV by D. Clouston.
X4 Satellite Structure by B. Collins.
Thermal Design and Analysis Aspects of Advanced Communication Spacecraft by B. N. Eddleston.
Fabrication Methods for Beryllium Spacecraft Components by R. G. W. Hathaway.
The Finite Element Analysis of Spacecraft Structures by R. G. W. Hathaway.
Structural Design of the Space Shuttle Orbiter by P. J. McKenzie.
Substrates and Solar Arrays by C. Raitt-Brown.
Low Speed Mechanism for an Array Drive by T. Rees.
Design of a Flywheel for Satellite Attitude Control by J. M. Standing.
Spacecraft Electrical Distribution by P. E. Whitehead.
Fatigue Testing for Vibration *(To be announced).*
Lightweight Rigid Solar Panels *(To be announced).*

* *Further offers of papers are invited at this and subsequent meetings.*

Special Note

While every effort will be made to include the above Papers in the final programme, the Society cannot be held responsible for any changes which may become necessary for reasons outside its control.

SCOPE OF CONTRIBUTIONS

1. **Main Papers**
   For reading at the meeting with a presentation time of between 20-30 min., plus questions. The Papers are normally published in the Society's *Journal.*

2. **Associated Papers**
   Authors who are precluded by reason of distance or other matters from attending personally, may also contribute a written MSS, to be submitted (with preprints if desired) and published as part of the Proceedings of the Meeting.

3. **Short Papers/Reports**
   Short papers may be presented (up to 10 min. duration) on aspects of particular interest which do not lend themselves to presentation as Main Papers, e.g. Research Reports, Current News, or other Statements of Interest. Notice of presentation must be given in good time to allow for incorporation in the final programme.

4. **Registration**
   Registration is necessary for all Main Meetings. Registration Forms are obtainable from the Executive Secretary on request.

EARTH OBSERVATION SATELLITES

To be held in the Large Physics Theatre, University College, Gordon Street, London, W.C.1.

11th–12th April 1973

PRELIMINARY LIST OF PAPERS*

The Skylark Earth Observation Platform by J. C. Abbott and R. J. Jude.
Attitude Stabilisation of Earth Observation Satellites by D. K. Anand and J. M. Whisnant.
Tropical Climatology from a Satellite by Dr. E. C. Barrett.
Techniques for the Remote Measuring of Air Pollution from Satellites by Dr. A. R. Barringer.
The Earth Resources Skylark – A Progress Report by B. S. E. Beattie.
Multispectral IR Line Scanner for use on a Space Shuttle by E. J. Becklake, N. Houston and W. G. Wilson.
ERTS-A Experiments Report by D. P. Bickmore.
Synoptic Observations at a Global Scale by Prof. K. M. Clayton and J. R. Tarrant.
Analysis of ERTS-A Imagery by W. Gordon Collins.
Meteorological Utility of High Resolution Multi-Spectral Data by J. M. Danko.
A Survey of Orbital Remote Sensing Technology by S. L. Entres.
International & Legal Aspects of Earth Observation Satellites by Prof. J. Hanessian.
Computerised Generalisation of ERTS-1 data by J. E. Hill and J. R. Tarrant.
Interpretation of Vegetation by J. C. E. Hubbard.
Land Resources Planning by M. A. Keech.
Combined Restitution of Aerial & Satellite Photographs for Topographic Mapping by Dr. O. Kolbl.
Remote Sensing Targets in Economic Geology by J. W. Norman.
EOS: Some Concepts for Data Interpretation by M. O'Hagan.
Interpretation of Skylark imagey by Digital Techniques by Dr. E. S. Owen Jones and N. D. E. Custance.
Satellites: What can they offer Hydrology? by Dr. R. B. Painter.
ERTS-A: Location of Locust Breeding Sites by D. E. Pedgley.
An Earth Resources Aircraft Facility in Preparation of a European Satellite Programme by J. Plevin.
Automatic Self-deployable high attenuation light shade for spaceborne sensors by F. W. Schenkel.
(Title awaited) by Dr. N. Simmons.
Earth Resources Mapping from Satellites by L. P. White.
Contribution of ERTS-1 Data to coastal zone management decisions by Dr. F. J. Webber.
The Use of Skylab & ERTS data in an Integrated Natural Resources Programme by J. L. Van Gelderen.

* *Further offers of Papers are invited for presentation at subsequent meetings.*

Special Note

While every effort will be made to include the above Papers in the final programme, the Society cannot be held responsible for any changes which may become necessary for reasons outside its control.

Spaceflight

Spaceflight is published monthly by the British Interplanetary Society, and is issued free to members.

Full particulars of membership may be obtained from the Executive Secretary at the Society's offices at 12 Bessborough Gardens, London, SW1V 2JJ: telephone 01-828 9371.

Correspondence and manuscripts intended for publication should be addressed to the Editor at 12 Bessborough Gardens, London, SW1V 2JJ

Opinions in signed articles are those of contributors, and do not necessarily reflect the views of the Editor or the Council of the British Interplanetary Society, unless such is expressly stated to be the case.

SPACE STUDY MEETING

Theme **Project Starship**

To be held in the Tudor Room, Caxton Hall, Caxton Street, London, S.W.1 on **10 January 1973** from 6.30 - 8.30 p.m.

A discussion meeting, initiated by Alan Bond, with contributions from other Speakers, on the propulsion requirements for an interstellar voyage. Members and their guests only.

LECTURE

Title **New Knowledge of the Sun** by Dr. J. C. Brown

To be held in the Tudor Room, Caxton Hall, London, S.W.1 on **26 January 1973,** 6.30 - 8.00 p.m.

No admission tickets are needed. Members may introduce guests.

LECTURE

Title **Studies of the Moon — 1** by Professor S. K. Runcorn

To be held in the Lecture Theatre, Royal Society of Arts, John Adam Street, London, W.C.2 on **13 February 1973,** 6.30 - 8.00 p.m.

No admission tickets are needed. Members may introduce guests.

LECTURES

Theme **Studies of the Moon — 2**

To be held in the Tudor Room, Caxton Hall, London, S.W.1 on **22 February 1973,** 6.30 - 8.30 p.m.

Two papers will be presented.

(a) Carbon Chemistry of the Moon by Dr.C.T.Pillinger.

(b) Lunar Seismology and Thermal Effects by Professor J.A.Bastin.

No admission tickets are needed. Members may introduce guests.

LECTURE

Title **New Maps of Mars** by C. A. Cross, FBIS.

To be held in the Tudor Room, Caxton Hall, Caxton Street, London, S.W.1 on **8 March 1973,** 6.30 - 8 p.m.

No admission tickets are needed. Members may introduce guests.

MAIN MEETING

Theme **Structures of Space Vehicles and Spacecraft**

To be held in the Architecture Lecture Theatre, University College, Gower Street, London, W.C.1 on **3 - 4 April 1973.**

Subject areas are as follows:—

(a) Thermal Analysis
(b) Substrates/Solar Arrays
(c) Mechanisms
(d) Fatigue Testing for Vibration
(e) Welded systems/structures
(f) Fracture Mechanics
(g) Advanced materials/techniques
(h) Quality Assurance

Offers of papers are invited.

Further details available from the Executive Secretary.

This meeting will be followed, on **5 - 6 April 1973,** with a meeting entitled 'Reinforced Plastics in Aerospace Applications' organised by the Plastics Institute. By special arrangement, those attending the Society's meeting will also be able to attend the subsequent meeting on payment of a specially reduced fee.

MAIN MEETING

Theme **Earth Observations Satellites**

To be held in the Large Physics Theatre, University College, Gower Street, London, W.C.1 on **11 - 12 April 1973.**

Subject areas are as follows:—

(1) *Advances in Earth Resources Applications*
  (a) Applications of Earth Resources Techniques (Geology, Agriculture, Marine etc.)
  (b) Development of Sensors (Cameras, IR Line Scan, Radar and Radiometry)
(2) *Earth Resources Projects*
  (a) Vehicles (Balloons, Aircraft, Rockets and Satellites)
  (b) Current & Future Projects (Skylark, ERTS-1, Skylab)
(3) *Ground Support Facilities*
  (a) Data Platforms
  (b) Data Processing (Visual Interpretation, Digital Data Processing)
  (c) Ground truth: Interpretation of results
(4) *Recent Experimental Results*
  (a) Skylark (b) ERTS-1 (c) Others
(5) *Organisation, Administration and Policy*
  (a) Management (c) Legal
  (b) International aspects (d) Economic

Offers of papers are invited.

JOINT MEETING

Theme **Electric Propulsion of Space Vehicles**

To be held at Culham Laboratory, Abingdon, Berks, on **10 - 12 April 1973.**

The following subjects will be included:—

(a) All types of electric thrustors
(b) Power conditioning, energy conversion and control of electric propulsion systems
(c) Installation of systems into space vehicles
(d) Assessment of missions pertinent to electric propulsion
(e) Testing of propulsion systems in the Laboratory environment
(f) Technologies and manufacturing techniques

Organised jointly by the Science Education and Management Division of the IEE and the UKAEA Culham Laboratory in association with the Institute of Physics, the R.Ae.S., and the B.I.S. Residential accommodation will be available at Corpus Christi College, Oxford and transport between Oxford and Culham Laboratory will be provided.

Offers of papers are invited.

Further details are available from the Executive Secretary.

LECTURES

Theme **The New Knowledge of the Sun — 2**

To be held in the Tudor Room, Caxton Hall, Caxton Street, London, S.W.1 on **25 April 1973,** 6.30 - 8.30 p.m.

Two papers will be presented.

(a) The Solar X-ray Spectrum

(b) Interaction of the Solar Corona and Magnetic field

No admission tickets are needed. Members May introduce guests.

13TH EUROPEAN SPACE SYMPOSIUM

Theme **International Collaboration in Space**

To be held in the Commonwealth Hall, Royal Commonwealth Society, Northumberland Avenue, London, W.C.1 on **25 - 27 June 1973.**

Subject areas are as follows:—

(a) Global Space Projects
(b) European Collaboration in Space Science
(c) European Collaboration in Space Applications
(d) Post-Apollo Collaboration
(e) Round-table discussions

This meeting will be co-sponsored by European space societies in France, Germany, Italy and the UK.

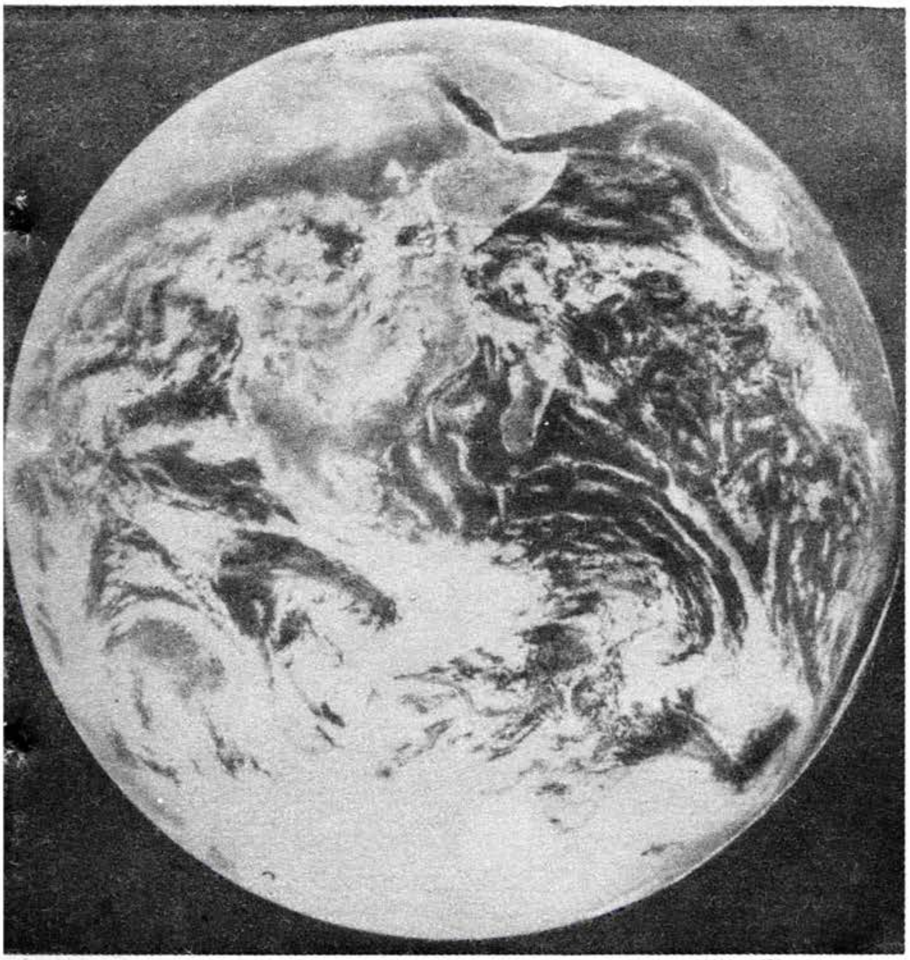
Further details are available from the Executive Secretary.

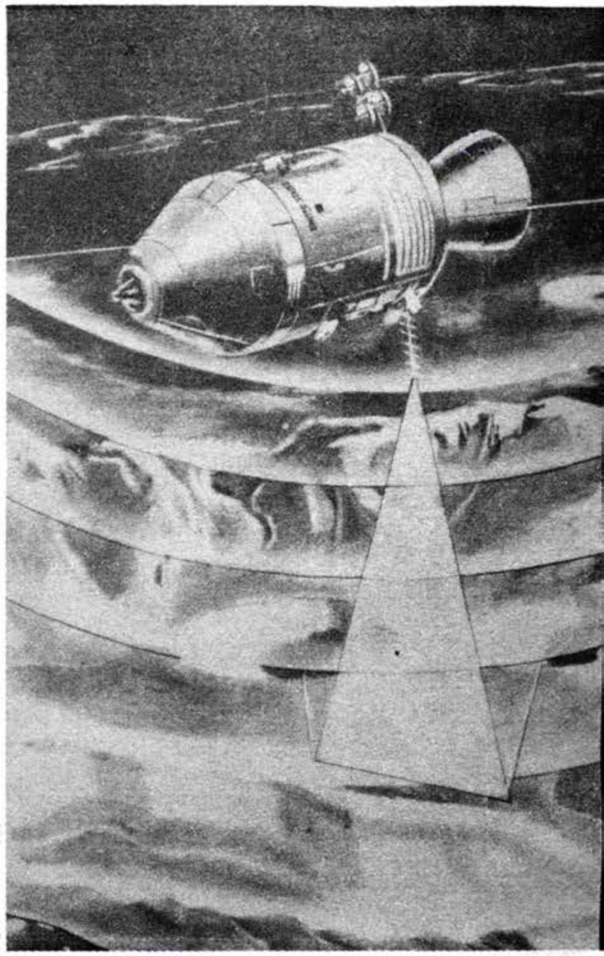
Printed by Unwin Brothers Ltd., at the Gresham Press, Old Woking, and Published by the British Interplanetary Society, 12 Bessborough Gardens, London, SW1V 2JJ.

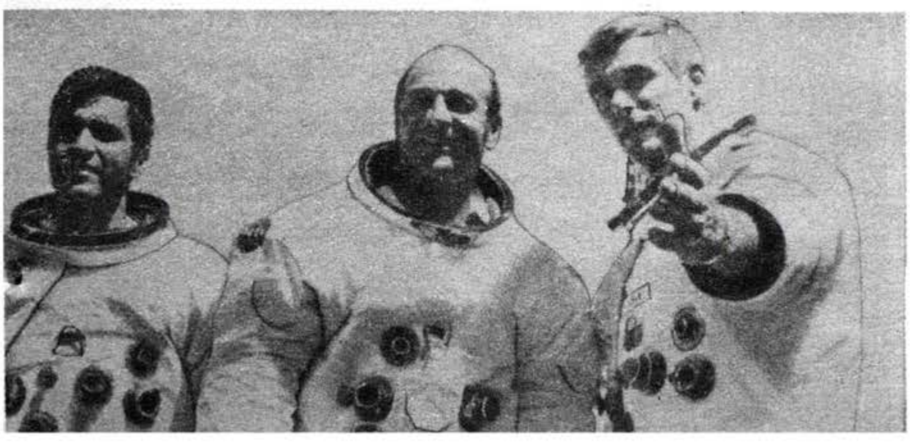
SPACEFLIGHT

88905 КОСМИЧЕСКИЕ ПОЛЕТЫ № Т-3
(спейсфлайт)
По подписке 1973 г.

Volume 15 No. 3 March 1973







Published by The British Interplanetary Society

Editor:
Kenneth W. Gatland, FRAS, FBIS

Assistant Editor:
L. J. Carter, ACIS, FBIS

CONTENTS

COVER

THE BLUE PLANET. The entire continent of Africa is seen in the photograph, *top left,* taken by the Apollo 17 astronauts as they returned from the Moon. It extends from the Mediterranean to the Antarctic south polar cap. At upper right centre is the Arabian Peninsula and the island at centre right is the Malagasy Republic. The Asian mainland is on the horizon at upper right. *Right,* how electronic 'divining rod' sounder system was used by the command ship 'America' to seek lunar below-surface metallic and possible water deposits. *Below,* Apollo 17 astronauts Jack Schmitt, Ron Evans and Gene Cernan. For story see page 87.

SPACEFLIGHT

A Publication of The British Interplanetary Society

VOLUME 15 NO 3 MARCH 1973 *Published 15 Feb. 1973*

MILESTONES

Dec

16 Service module engine starts 'America on course for home from lunar orbit at 11.33 p.m. GMT.

17 Ronald Evans during EVA recovers film containers from service module SIM bay.

19 Command module of 'America' splashes down in Pacific 400 miles from Samoa at 7.25 p.m. GMT.

20 European Space Conference in Brussels agrees the creation of a European Space Agency by the fusion of ESRO and ELDO, if possible by 1 January 1974; also agrees in principle the following projects: (a) Post Apollo Sortie Module. (b) French launch vehicle L-3S, whereby Europa III is abandoned. (c) Rationisation of the various European satellite projects, including the U.K. Geostationary Test Satellite which was originally intended to replace Black Arrow as a national programme. Countries to decide individually which projects they will support and fix their own level of financial commitment.
N.B. If no other existing projects are cancelled, costs over the next 8 years would be roughly as follows:

L-3S Launch Vehicle	$540 million.
Post Apollo Sortie Module	$275 million.
Europa II completion*	$61 million.
ESRO and national satellites under construction or planned	$800 million.
	$1676 million.

* *Future of Europa II to be considered at ELDO Council meeting on 2 February.*

Jan

8 Soviets launch Luna 21 by Proton rocket from Baikonur cosmodrome at 9.55 a.m. (Moscow time) 'to further scientific studies of the Moon and near-lunar space'.

10 To reduce current $3,400 million space budget by $200 million required by Nixon Administration, NASA stops work on High-Energy Astronomical Observatory (HEAO) programme; Applications Technology satellite (ATS) G, and all nuclear propulsion, including Nerva, and large nuclear power generation systems.

12 Following course-correction on 9 January, Luna 21 enters lunar orbit of 90-110 km inclined at 60 deg. to equator; period 1 hr. 58 min.

13-14 Thrust corrections adjust orbit of Luna 21 to give a minimum distance from lunar surface of 16 km in preparation for landing.

16 Luna 21 soft-lands inside Lemonnier crater near eastern rim of Sea of Serenity at 1.35 a.m. (Moscow time) and discharges 840 kg Lunokhod 2 from ramp on to surface at 4.14 a.m. (Moscow time). In addition to Soviet research equipment 8-wheeled robot carries French-built laser reflector.

17-18 After recharging chemical power sources from solar panel, Lunokhod 2 begins first period of lunar exploration after manoeuvring near landing stage.

MODULAR SPACE STATION FACILITIES

By P. J. Parker

Introduction

The advent of the Space Shuttle transport system in the late 1970's promises to provide an economical, reliable and frequent access to the environment of space. By using the Space Shuttle for orbital build-up, logistics delivery and return transportation it will be possible to establish a near-Earth orbit, long-term, manned scientific Modular Space Station [1]. Several Phase-B studies of such a space station have been conducted by contractors to the National Aeronautics and Space Administration. The McDonnell Douglas Astronautics Company concept is shown in Fig. 1.

The Modular Space Station will be designed to offer a broad range of resources to the potential researcher by providing flexible onboard facilities for scientific, technical and commercial investigations and applications. It would operate as a general purpose laboratory by providing specific services common to many research and application programmes, such as data processing, optical calibration, data displays and maintenance facilities. In addition, the Modular Space Station will be able to support many attached or free-flying Research and Application Modules (RAM's) that would be dedicated to specific projects like astronomy or Earth observations.

How well man uses the environment of space to benefit himself will depend, in a large part, on how effectively the facilities of the Modular Space Stations are utilised by researchers. What are these facilities likely to be? The following notes, based upon McDonnell Douglas Astronautics Corporation studies of the Modular Space Station, describe some of the main proposals.

Modular Space Station

The Space Station will be incrementally assembled, in orbit, from modules of 4.3 metres diameter and up to 17.7 metres long delivered by the space shuttle transport system. The Initial Space Station (ISS) will comprise, in order of launch, a Power/Subsystems module, a Crew/Operations module and the General Purpose Laboratory (GPL) module.

The GPL is of primary interest to the potential scientific researcher. Seven docking ports are available on the ISS for logistics modules and attached or free-flying RAM's. About 1/3rd of the station's internal volume will be available as

POWER/SUBSYSTEMS MODULE

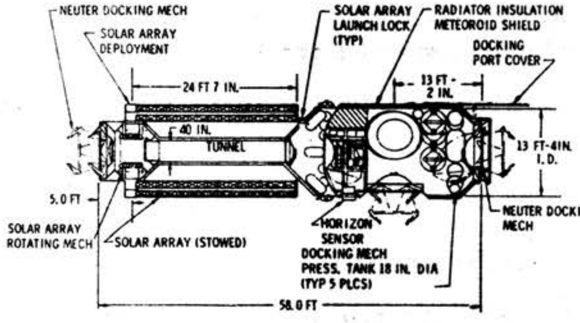


Fig. 2. Power/Subsystems Module of Modular Space Station.

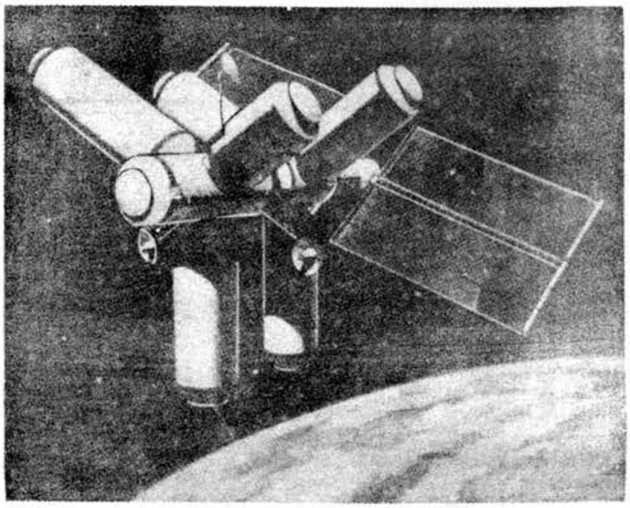


Fig. 1. McDonnell Douglas concept of Initial Modular Space Station.

laboratory space and over 40% of the electrical power produced is available for experiments. Table 1 lists other pertinent data. A Growth Space Station (GSS) will be achieved by the launches of 2 extra modules, another Crew/Operations module and a further Power/Subsystems module. The GSS would be achieved about 5 years after initiation of on-orbit Space Station operations though this would depend entirely upon experience with the ISS, financial constraints and the desirability of a growth version. At least 10 years operations with the Modular Space Station are planned.

General Purpose Laboratory (GPL)

The GPL will provide a series of facilities to support space experiments and operational systems. It contains the major equipment and facilities required to support, service and maintain internal and modular experiments, as well as equipment and facilities to do physical testing, repair and maintenance of space station subsystems. The GPL will be flexible and will respond to programme changes whilst operating in orbit. The main requirement for the GPL arises from the need to support research programmes in which only experiments have been defined in broad terms. Therefore, the GPL primary functions have been organised into functional laboratories, as follows:

(a) Electrical/electronics laboratory
(b) Mechanical sciences laboratory
(c) Experiment and test isolation laboratory
(d) Hard Data Process Facility
(e) Data evaluation facility
(f) Optical sciences laboratory
(g) Biomedical and biosciences laboratory
(h) Experiment/secondary Command and Control Centre

These laboratories will support the analysis or testing of experiments/subsystems; disassembly, assembly and repair; parts storage; component replacement; calibration; work area restraints; experiment physical accommodation and experiment performance equipment functions. Each piece of laboratory equipment will have foot-restraints to permit 'hands-free' operation and all work tables will have restrain-

Table 1. Modular Space Station Characteristics

Orbit	445-500 km, 55-deg. inclination.
Mission duration	5-years (ISS) 10-years (GSS).
Station Crew Complement	6 persons (ISS), 12 persons (GSS).
Experiment Man-hours/day	46 (ISS), 95 (GSS).
Maximum Man-hours/day	60 (ISS), 120 (GSS).
Laboratory Facilities	200 M^3.
Power for experiments	4.8 kwe (ISS), 12.1 kwe (GSS).
Pointing and stabilisation	All-attitude capable. Inertial and Earth-centred data available. 0.25-deg. accuracy, drift of 0.005-deg./sec. or less.
Navigation	Ground based.
Data management	Computer-managed, quick-look capability. Up to 9072-kg/year of film and tape processed.
Communications	Multichannel voice, two-way colour TV. Relay satellite capability of 10^{12} bits/day.
Gravity	10^{-5} g. (nominally).
Payload-to-orbit	73,000-kg/year at about 30-day intervals.
Atmospheric pressure	101 kn/m^2 O_2/N_2.
Humidity Control	0.45 kg/day (not crew).

ing or holding devices to keep experiment items or tools in place. Strategically located in work areas are communication facilities and emergency suit pressurisation and breathing attachments. All work areas have appropriate fire-fighting equipment. Throughout the GPL, a clear access of 1.5 metres in diameter is provided. Running along the top of this accessway will be a rail track for a small trolley for transporting large items in the GPL.

Electrical/Electronic Laboratory

The main service facility in the electrical/electronic laboratory will be the multi-instrument test bench and console which is required for checkout and contingency repair of electrical and electronic equipment. The instruments in the multi-instrument test bench can be unplugged and used as portable test equipment. A small built-in miniature laminar flow glove box will be available for cleaning, assembling, disassembling and soldering of 'clean' components. The laboratory will provide all the instrumentation, test gear,

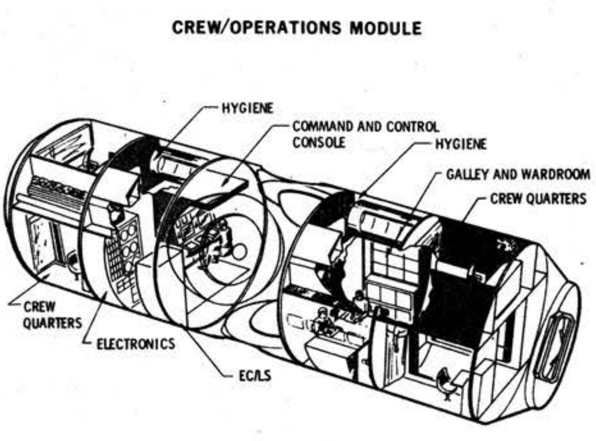


Fig. 3. Modular Space Station Crew/Operations Module.

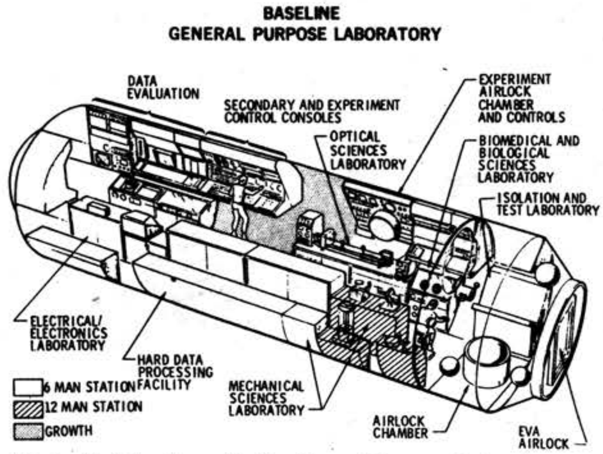


Fig. 4. Modular Space Station General Purpose Laboratory.

stimuli, controls and displays needed for testing, electronic calibration and maintenance of experiments and subsystems. As a minimum, it will include an oscilloscope; hardcopy data recorders; voltmeter; power supplies; signal generators; signal analysers; test sets; small patch panels and test connectors; continuity checkers; multimeters; timers; frequency counters; transducer calibration units (vacuum, pressure and temperature); special hand tools and mounting fixtures.

Mechanical Sciences Laboratory

The main feature of this laboratory will be the laminar flow glove boxes with chemical and gas capabilities for heavy duty, light duty and specialised functions. They will be used for assembly, disassembly, repair, replacement, purging, cleaning, lubricating and calibration of items of subassembly size. Zero-g hold-down will be provided, in the glove boxes, for items subject to disassembly. Also provided in this laboratory will be a metallograph tester; thermostructural tester; X-ray diffraction unit; X-ray generator and a specimen structural tester for performing and analysing material sciences experiments. A precision work fixture will also be supplied.

Experiment and Test Isolation Laboratory

Providing the capability to isolate toxic liquids, gases, molten solid materials and high pressures, this laboratory will include the facilities for conducting experiments, maintenance and operations isolated from the space station. It will include a 1.25 metre diameter airlock chamber for experiments that will involve exposure directly to the space environment. A chemistry and physics glove box, with a storage and analysis console, will also be provided for experiments and operations requiring chemical handling. Experiments will be operated remotely from a monitoring and display console after experiments have been set-up and the laboratory sealed.

Hard Data Process Facility

This facility will provide the capabilities and equipment related to film handling, and processing, preliminary film calibration and 'quick-look' film data evaluation. The film storage cabinet in the laboratory will provide radiation protection and temperature stabilisation, maintaining predictable, consistent and satisfactory film quality. The facility will also provide the equipment to develop film,

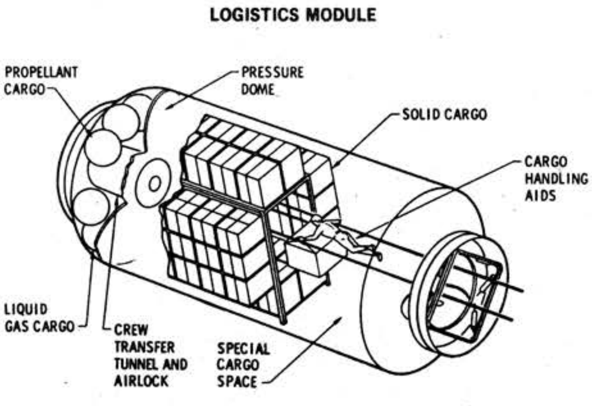


Fig. 5. Logistics Module (Transported by Shuttle).

produce microfilm, calibrate developed film and perform basic analyses of test strips. It will also include plate and film processors (black and white, colour, high resolution and quick access); microfilming equipment; spectrometer; densitometer and a light table. Processed film will be of archival quality and can be either stored, microfilmed for Earth-return or electronically scanned for transmission to Earth.

Data Evaluation Facility

This facility will contain equipment to analyse, reconstruct, mensurate, store and retrieve experimental and operational data. The facility works in conjunction with the Space Station data management system to provide a complete complement of hardware and software for handling space station data. It will include an automatic film scanner, stereo viewer, multi-format viewer editor, light table and a colour film and plate processor. It includes those capabilities that are associated with the availability of film, video, analog and digital data as well as handling, processing and evaluation facilities for such data.

Optical Sciences Laboratory

The laboratory will include equipment for conducting optical or spectral alignments, calibration, troubleshooting or set-up on such items as telescopes, cameras, scanners, navigation equipment, attitude stabilisation equipment, electronic imagers, rendezvous/tracking equipment and other units that require optical checkout. It will have a scientific airlock chamber that will accept a 0.61 metre diameter scientific experiment package that requires exposure to the space environment. A stable platform in the airlock chamber provides for the precision mounting of experiments. Associated with the airlock chamber is an optically flat, broad spectrum transmission window that permits documentary photography or visual inspection of deployed experiments or external phenomena.

Biomedical and Biosciences Laboratory

The equipment in the bioscience portion of the laboratory will consist of plant lighting, photo/TV coverage, time and specimen identification, plant and cell chemistry and special holding devices, flight launches and optics for invertebrate research. In the biomedical facility there will be an electrocardiogram, vectorcardiogram, bicycle ergometer, body mass measurement device and a lower body negative pressure device. There will also be equipment available for zero-g blood and urine analysis. For biological work requiring isolation or separation from the space station environment, a biological glove box is provided.

Experiment/Secondary Command and Control Centre

This centralised operation centre will monitor and manage the experiment programme of the GPL, attached RAM's and free-flying RAM's. In the event that the crew are forced to evacuate the Primary Command and Control Centre located in the Crew/Operation Module, the Experiment/Secondary Command and Control Centre would be capable of providing emergency/backup vehicle and subsystem control capability. The controls and displays are basically

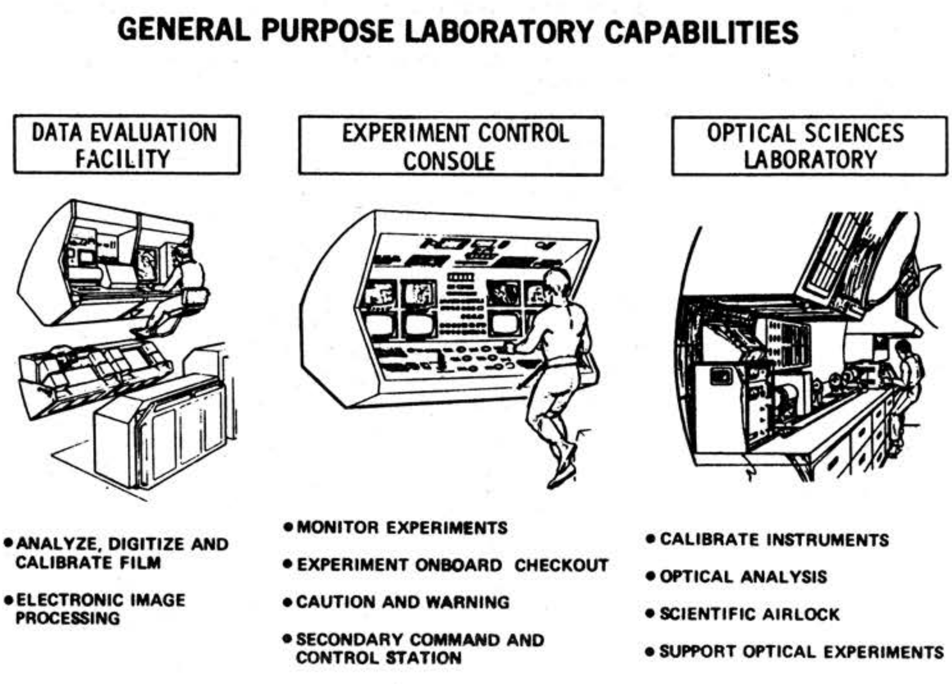


Fig. 6. One of the objectives of the General Purpose Laboratory is development of a water pollution measurement technique from orbit. Occupying only about 1% of the crew's time over a period of 1 year, the equipment employed is justified not by this single experiment but by its repeated use in scores of different activities over a period of at least 10 years. Many other GPL functions described in succeeding charts would operate in a similar way. Sensors include a metric camera (wide-area photographic coverage), multi-spectral camera (multiband photographic coverage), and multi-spectral scanner (multiband IR data), and observation telescope (crew viewing).

the same as those at the Primary Centre with additional dedicated displays and controls for monitoring and controlling the experiment programme. The experiment centre is designed for fully independent two-man operation. The Experiment/Secondary Command and Control Centre will possess multi-purpose display and input devices (computer-driven CRT's linked to the computer facility) video surveillance monitor (compatible with commercial colour 525-line standards); colour discriminator (to enhance data comparison operations); alphanumeric displays; warning matrix (to alert the crew of failures or error conditions); caution and display equipment; voice message generation unit (computer generated and composed phrases,of up to 4 discrete words from an internal vocabulary,for caution and warning and operational information); status lights; microfilm viewer; dedicated displays; programmable function keyboard; dedicated switches; hand controller (for performing manual steering operations, operating thrustors and aiming sensors/cameras at specific 'opportunity targets') and a printer unit (for uplink, unattended message relay).

Potential Research Areas

The broad range of resources offered by the General Purpose Laboratory of the Modular Space Station will enable a whole series of scientific and technical research programmes to be undertaken in the unique space environment. Potential research areas in several disciplines are:

(1) Astronomy

(a) Improved understanding of strong galactic X-ray sources and search for new sources.
(b) Increased knowledge of the spatial structure of astronomical objects and detection of faint objects.
(c) Understanding of solar processes through high-resolution observation of the Sun's granular structure and areas of high solar activity.
(d) Mapping of the entire sky in the ultraviolet region of the spectrum,with concentration on strong ultraviolet sources.
(e) Determination of the characteristics of X-ray and gamma-ray sources.
(f) Infrared survey of the sky to determine the sources of infrared radiation and their characteristics.

(2) Life Sciences

(a) Understanding of the fundamental roles of gravity and a cyclic environment in biological processes on Earth.
(b) Enhancement of Man's capabilities in space and advancement of medicine through use of environmental factors of spaceflight for applied research.

(3) Earth Observations

(a) Development of the technology for the remote sensing of the Earth's resources and improvement of the knowledge of the Earth and its atmosphere.

(4) Communications and Navigation

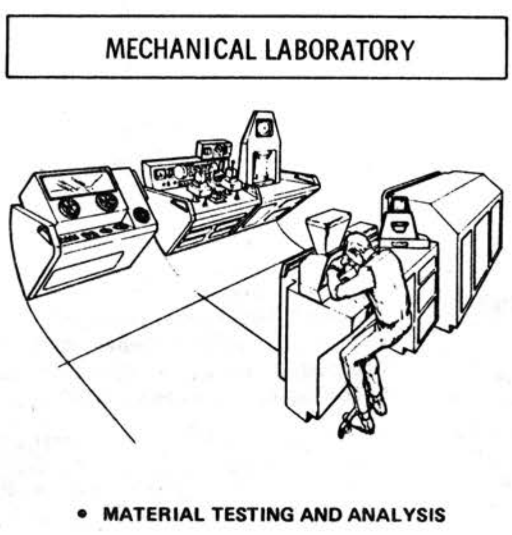
(a) Support broad research programmes by conducting performance testing of candidate configurations and techniques under actual conditions.

(5) Space Physics

(a) Improved understanding of the space environment and the induced environment surrounding the Modular Space Station.

(6) Materials and Processes

(a) Establish the technology of processing materials in the zero-gravity and vacuum environment of space for scientific and potential commercial purposes.



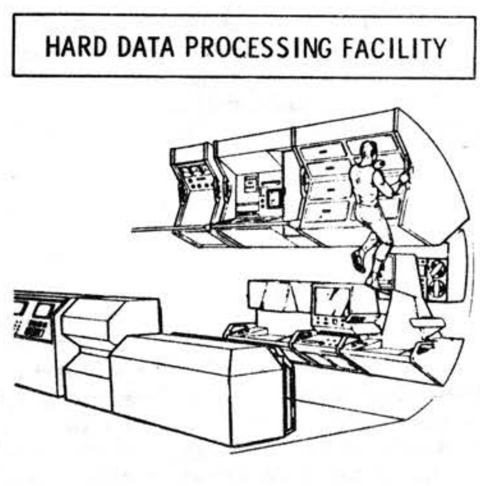
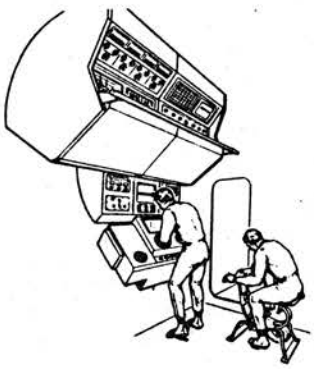


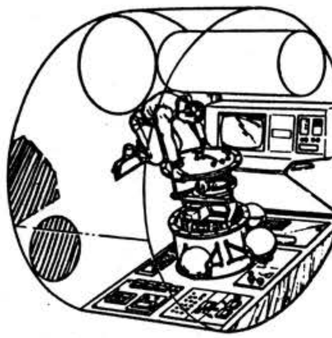
Fig. 7. The Mechanical Sciences Laboratory supports many types of mechanical, electro-mechanical, and chemical functions. It contains laminar flow glove boxes with chemical and gas capabilities – also X-ray and structural test equipment. The Hard Data Processing Facility has equipment for film storage, handling, processing, preliminary calibration, and 'quick-look' data evaluation.

BIOMEDICAL/BIOSCIENCE LABORATORY



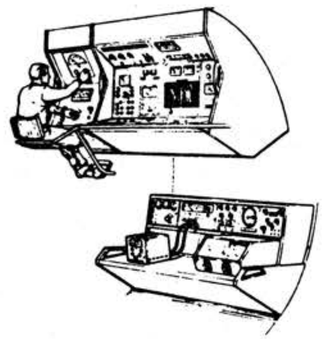
- FLIGHT CREW WELL–BEING
- BIOSCIENCE RESEARCH
- SPECIMEN PREPARATION
- FLUID ANALYSIS

EXPERIMENT AND TEST ISOLATION LABORATORY



- ISOLATED EXPERIMENT OPERATIONS
- CHEMISTRY AND PHYSICS EXPERIMENTS
- SCIENTIFIC AIRLOCK
- REMOTE OPERATION

ELECTRONIC/ELECTRICAL LABORATORY



- ELECTRONIC CALIBRATION
- CHECKOUT AND DIAGNOSTIC STIMULI
- MULTI–INSTRUMENT TEST STATION
- ELECTRONIC WORK BENCH

Fig. 8. The Biomedical/Bioscience Laboratory provides for monitoring of astronaut wellbeing, micro-biological research, plant physiology and invertebrate research. The Experiment and Test Isolation Laboratory is used to isolate experiment operations from the Space Station environment, including toxic liquid, gases and molten materials. The Electrical/Electronic Laboratory contains all the support equipment required for checkout and repair in support of experiments and, if necessary, Station sub-systems.

Conclusion

Following the 'giant leaps' of the past and present decades, the establishment during the 1980's of a 10-year-plus, manned Modular Space Station will give Man his first definite foundations in space. The lessons to be learned from operating such a facility may be used to establish the cornerstone of a new, 3-dimensional human civilisation that lives, rests and operates in the space environment [2].

It will be important, therefore, that the facilities of the Modular Space Station are utilised wisely by the scientific and technical communities. This will only be achieved if researchers are aware of the tools and facilities at their disposal. In a small way, it is hoped that this article may have assisted potential space station researchers. It must be remembered that the foregoing information was based on data from preliminary design studies and, therefore, may not be the final configuration selected by NASA.

Acknowledgements

The author wishes to thank the McDonnell Douglas Astronautics Company for supplying information on their Modular Space Station Phase B study performed for the George C. Marshall Space Flight Center under NASA contract NAS 8-25140. Especially, he wishes to thank Donald R. Steiss, McDonnell's European representative, for his continued assistance; also, the Public Affairs staff of NASA's Manned Space Flight Center, Houston and Headquarters, Washington, D.C. U.S.A.

REFERENCES

1. Henderickx, Herman, 'A Modularized Space Station', *Spaceflight,* **13**, 9, pp. 341-343 (1971).
2. Ehricke, Krafft, 'Our Commitment to Space', *Spaceflight,* **13**, 3, p.82 (1971).

NEXT MONTH – A SPACE PROBE FROM ANOTHER WORLD?

The astonishing idea that a space probe from another civilization may have entered the Solar System, and might be trying to make contact by returning signals to us in the form of a code, was widely reported in December. The hypothesis, by Duncan A. Lunan, a graduate of Glasgow University, suggests that the delay times of return signals, or 'echoes', varied from one signal to the next and could be interpreted as star maps identifying the probe's origin as the double star Epsilon Boötis and putting its arrival here some 13,000 years in the past. The question raised is whether these long delayed echoes have a natural explanation, e.g., are produced by disturbed conditions in the Earth's magnetosphere, in which case Lunan's interpretation is purely subjective. The paper – 'Space Probe from Epsilon Bootis', including 7 of the star maps, will be published in the April issue of *'Spaceflight'*. Other articles in this special 'New Frontiers' issue include 'The Interpretation of Signals from Space' by A. T. Lawton, and 'CETI Questionaire'.

In view of the undoubted interest which this paper will arouse, an opportunity is being given to interested members to meet Mr. Lunan and to hear an account of his researches at first hand. Mr. Lunan will present a more detailed appraisal of his studies at a special meeting of the Society to be held in the York Hall, Caxton Hall, Caxton Street, London, S.W.1. on **29 March 1973** *from 6.30-8.30 p.m.*

Members and their guests are cordially invited.

THE LAST APOLLO – 2

By David Baker

Continued from February issue, page 47]

Trans-Lunar Injection

Trans-Lunar Injection was completed and soon the command and service modules slipped their shackles and jettisoned, leaving the Lunar Module 'Challenger' exposed on top of the S-IVB. Turning around, astronauts Cernan, Evans and Schmitt rode their command ship 'America' into a docking with the LM, smoothly extracting it from the spent stage. Within a few hours the SPS engine in the service module had been fired for 1 second to execute the only course correction necessary for the entire outward leg.

The trajectory was longer this time (nearly 80 hr.) than any hitherto,to avoid spending several hours in the Moon's shadow on shorter routes which could otherwise place critical demands on the thermal control system.

The early portion of the flight gave its fair share of concern. One of the docking latches failed to engage properly, a spectacular shower of paint flakes streamed past the windows of the command module, the caution and warning system buzzed and flashed incessantly, and gastric upsets plagued Cernan. Several times during the flight the crew overslept. During the second sleep period, music, voice calls, klaxons, sirens, bells and alarm tones were all employed before the sleeping trio could be awakened from their slumbers.

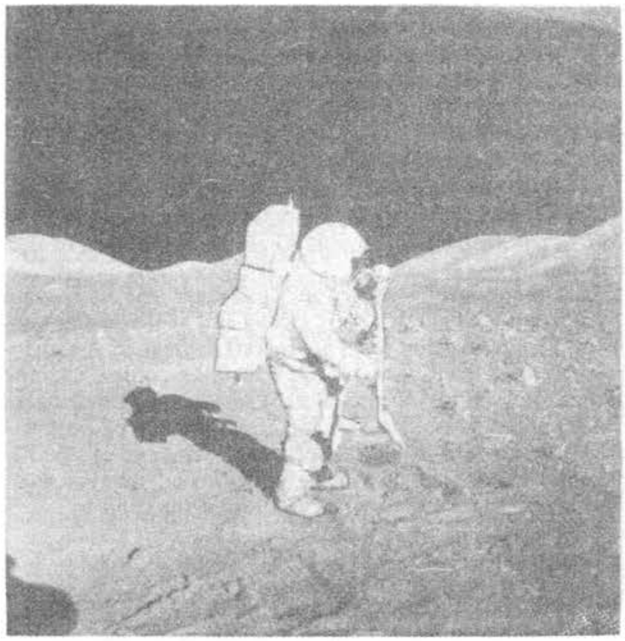
By that time the mission had settled down into unprecedented normality and gave promise of fulfilling all its expectations. Schmitt was moved on several occasions to provide Earth-watchers with a meteorological report. He philosophied: 'One could not look at that fragile blue globe and not think about the ancient sails of life that are crossing its path and wander ahead up to the present to the modern sails of life that are represented by men that developed out of that life. These men are today working towards the same end, that is, to put life farther into the Universe'.

Approaching the Moon a minor problem displayed itself in a cryogenic hydrogen tank, that region of the spacecraft where oxygen tanks on an earlier flight had crippled the service module and turned the LM into a lifeboat. On this flight the heaters were cycling on and off with rapidity but a diagnosis by the crew gave confidence that the problem was minor.

Close to lunar orbit insertion Schmitt got his first view of the Moon. His comment? 'Boy, is it big!' Who has need of poets with spontenaity of this calibre? Soon Apollo 17 had disappeared behind the western limb. The big engine burn of the service module, decelerating the 100,000 lb. mass by more than 3,000 ft/sec, was performed on the far side of the Moon,placing the combination CSM and LM in a 58 x 196 mile orbit. For this mission the spacecraft were required to steer an 11° plane change into the burn, exceeding any achieved on earlier flights. Thirty-three minutes after loss of signal the 2 docked vehicles reappeared on schedule. When the Goldstone tracking station had established lock,the confirmation of a good burn was prefaced by 'You can breathe easier. 'America' has arrived on station for the challenge ahead'. Cernan added, 'That was probably the smoothest and quietest SPS burn I ever remember'.

Mission Clocks Reset

Almost exactly at the planned time Apollo 17 had arrived in lunar orbit, making up the 2 hr. 40 min. delay at launch. By now all the mission event clocks had been put forward by this amount and the flight proceeded as scheduled.



Apollo 17 scientist-astronaut Jack Schmitt collects rake samples near the Taurus-Littrow landing site. The geological hand tool was used to collect discrete samples of rock and rock chips ranging in size from 1.3 to 2.5 cm.

All pictures United States Information Service.

Minutes after acquisition of signal on the first revolution the S-IVB, third stage to Saturn V, slammed into the Moon, gouging a crater more than 100 ft. in diameter and sending shock waves reverberating through the outer layers of the substructure. On the second revolution Schmitt reported a flash of light on the surface, a fact that could neither confirm nor deny the presence of an impact due to the echoing waves from the S-IVB. He responded with a, 'Just my luck!'

Now came the implementation of a changed procedure. It always had been difficult to accurately guide the 2 spacecraft into an orbit that at the low point would place the LM at its required altitude for powered descent initiation. The risk of an overburn was high, with a 1 second shutdown error placing both vehicles on an impact trajectory. In any case, sweeping around the eastern limb that low would not provide sufficient time for updated doppler tracking on the lunar module's position. So 2 changes had been conceived and would now be carried out.

At the beginning of revolution 3, with both spacecraft still docked, the SPS engine was again fired for nearly 23 sec. to change the orbit to 15.5 x 68 miles. The low point is here twice as high as on previous flights where the descent orbit insertion manoeuvre had been performed by the command and service modules, still too high for the start of powered descent but the lowest that both vehicles would venture together. Also, that low point was considerably downrange of the subsequent point of powered descent. The vehicles would still be descending as they passed this area, unlike earlier flights. This had the desired objective of swinging the orbital path farther out in space, permitting acquisition of signal some 3 minutes earlier and thus achieving the second objective.

Landing Preparations

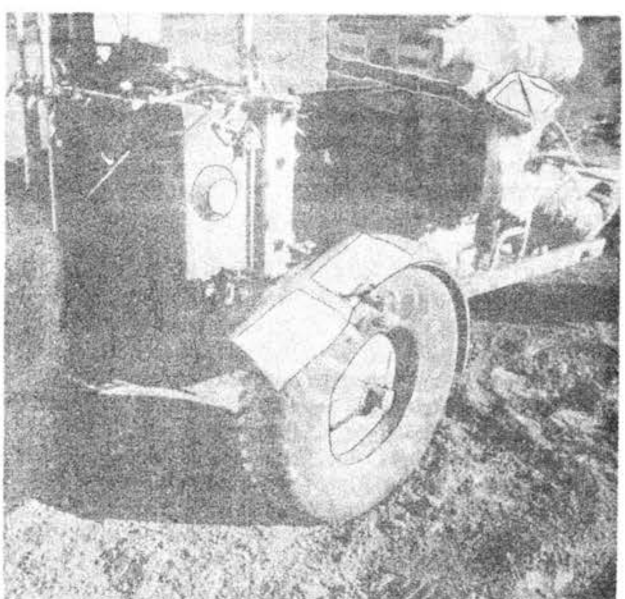
The crew slept. For the last time preparations were in the offing for a manned descent to the lunar surface. Awakened to the tune, 'Good morning America', Cernan and Schmitt prepared to man the LM they called 'Challenger'. Ron Evans would be alone in the command module longer than any of his 6 predecessors.

For 9 revolutions the 2 craft remained locked in this 15.5 x 68 mile orbit, slowly distorted by the mascons of *Mare Serenitatis* and lesser perturbations in the mass of the Moon.

With the crew now settled in 'Challenger' and its systems checked out, the hatches were closed and at the beginning of the 12th revolution the 2 spacecraft separated. A short 3 sec. burn of the service module's reaction control engines started the CSM on its gradual drift away from 'Challenger'. For the entire front side pass the 2 vehicles moved farther apart and less than 90 min. later, near to the end of rev. 12 and some 5,200 ft. away, the SPS engine on 'America' was fired again for a brief 4 sec. to circularise the orbit to 62 x 81 miles.

Just 6 min. later 'Challenger' fired its reaction control engines for 27 sec. to trim down the low point of its own orbit to just 40,000 ft. above the landing site radius, but still downrange of the landing site proper and a manoeuvre performed with RCS engines alone for the first time. In essence the descent orbit insertion manoeuvre for Apollo 17 was a 2-stage hybrid performance between the SPS engine on 'America' and the small RCS engines on 'Challenger', spaced 10 revolutions apart.

Apollo flights 10,11 and 12 had all used the lunar module's descent engine to lower the orbit for powered descent. Flights 14, 15 and 16 had used the SPS engine in the service module to conserve descent propellent in the LM. By using spare RCS propellent the LM is made 40 lb. lighter permitting 3 sec. additional hover time on approach, and conserving some 25 ft/sec. in the SPS tanks for possible contingencies, with the mother ship only going part way to the required perilune.



Traverse maps provide a substitute dust guard for a back wheel of the lunar roving vehicle. Part of the guard was knocked off during the first EVA. Seated at right is Jack Schmitt.

At acquisition of signal the LM announced itself ready for the final descent. Once before its commander had been this close, and there were parallels that could be drawn from his voice. Almost exactly on the Flight Plan time 4 RCS engines lit up and 7 sec. later the big descent propulsion system started its 12 minute burn. Twenty-six seconds later the engine had throttled up from its 10% ignition rate exerting a force of 0.5g.

All the way along the 280 mile flight to touch-down, 'Challenger' behaved like the lady she was. Cernan and Schmitt were to put her down only seconds later than planned with ease and ample reserves for hovering. The touch-down of any lunar module is never soft and the sudden backward jerk that warned that a rear footpad was in a crater startled both crewmembers. They had landed on time at 19.55 GMT, 11 December 1972.

First EVA

The first EVA was scheduled to begin 3 hr. 38 min. later and after descriptions of the area in which they had landed Cernan and Schmitt began preparations for their excursion. The first EVA, nominally of 7 hr. duration, would concentrate on the deployment of the ALSEP instruments and provide an opportunity for a short geological traverse 2½ km south east of the touch down point.

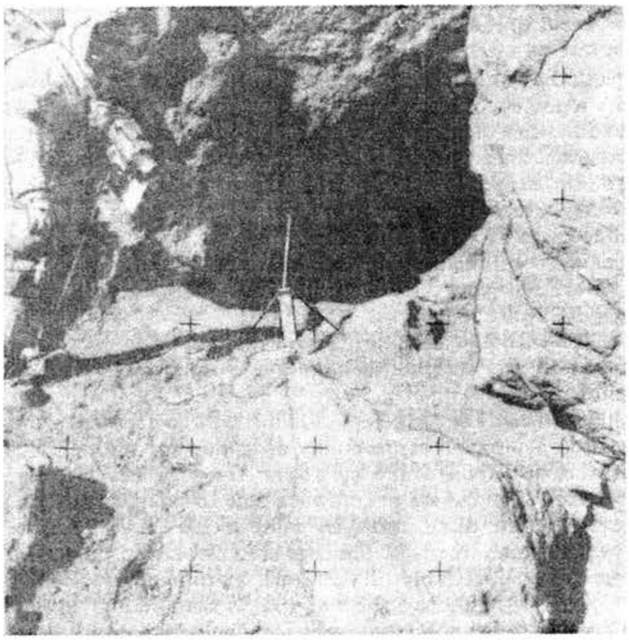
The lunar surface timeline was 3 hr. 59 min. old when depressurisation of the ascent stage signalled the start of EVA-1, some 21 min. late. For the first time a TV camera could not witness the initial activities on the Moon. The time required to relocate the device from its usual mount on the side of the LM was saved in favour of extra time for unpacking the equipment.

As planned Cernan was first to set foot on the surface. His first words were, 'As I step off at the surface at Taurus-Littrow we'd like to dedicate these first steps of Apollo 17 to all those who made it possible. Jack, I'm out here. Oh! my golly! Unbelievable! Unbelievable! But is it bright in the Sun!'.

During the many activities associated with preparations for the ALSEP deployment including off-loading the lunar roving vehicle, test driving, setting up the equipment racks, deploying the flag and extracting the subpallets of instruments, the crew were expending up to 1300 BTU and repeated warnings urged them to go easier. Right on the timeline Cernan struggled away to find a suitable site and minutes later Schmitt brought the LRV up, carrying the drill on the passenger seat.

The first experiment to be deployed was the Heat Flow or HFE. Consisting of a series of thermal sensors (platinum resistance thermometers) the 2 strings are lowered into 2.6 metre deep bore holes lined with the stems that serve to prevent collapse and permit a smooth tube for the entry of the thermal sensors. A rammer is used to push the probes fully home and a thermal closeout shield prevents heat loss. The HFE was originally flown on Apollo 13, the aborted lunar landing mission, and again on Apollo 15 when trouble was experienced with the drilling, preventing full penetration; and finally on Apollo 16 when the sensor data cable was inadvertently ripped from its socket.

The HFE was added to the scientific inventory of Apollo 17 only when serious consideration had been given to the



Apollo 17 commander Gene Cernan stands beside an over-hanging rock. At center is a gnomon, used as a photographic reference to verify local vertical, Sun angle and lunar colour.

effects of the Apollo 16 loss. It was not on the original list. A strain release fitting had been added to prevent a similar accident.

While Cernan was deploying the HFE Schmitt set up the Lunar Surface Gravimeter, a device designed to sense the outflowing gravitational waves generated from the acceleration of masses as predicted by Einstein's general theory of relativity. The LSG is essentially a distant outpost for calibrating and endorsing the sensory apparatus on Earth. Should vibrating waves be detected in the Moon at the same time as similar tides on Earth then earlier suspicions that gravity waves have actually been recorded on Earth will be confirmed.

The equipment consists of a modified La Evete-Romberg gravimeter comprising a mass suspended on a spring in a fused quarz glass frame. The suspended beam, pivoted at one end and connected to the spring, is balanced between 2 capacitor plates for electrical measurement of the characteristic vibration. The thermal flux must be constrained to within 1×10^{-6} deg. F and a shield is attached to the upper portion of the box to prevent direct exposure to the Sun's rays. The extreme sensitivity of the equipment makes it possible to sense variations in the gravity field to within 10".

Now came deployment of equipment in support of the Lunar Seismic Profiling experiment, a further extension of the investigation of the subsurface layers. LSP consisted of an array of 4 geophones, all interconnected and laid out in the centre and at each corner of a 90 metre equilateral triangle. A flag marked the location of each geophone and the data module was itself connected by telemetry tape to the central station, the communications relay for all ALSEP experiments. The geophones are similar to those deployed for the Active Seismic Experiment of Apollo 14 and Apollo 16. On each of those 2 flights a thumper device was used by the crew to generate seismic waves, followed by the ejection of grenades after the crew had left the surface. The LSP experiment would use 8 explosive packages left at distances from 150 metres to 2-7 km, these also to be detonated after the Apollo 17 crew had left, but this time in situ. The explosive packages contained charges varying from one eighth lb. to 6 lb. and were to be armed by initiating 2 delay timers by releasing 3 pins on each package. A remote antenna, set down 10 metres away from the central station, allowed ground commands to detonate the charges when the timers opened a 2 hr. 'firing window' between 91 and 94 hr. after the crew deployment depending on the charge.

The explosive packages were transported on 2 pallets stowed on the LRV, set down on the surface, with a 12-section antenna raised some 69 in. to receive firing commands. Three independant commands would be sent after the 3 arming pins had been pulled, ensuring safety for the crew. The LSP is capable of probing a region 4 km beneath the surface.

When measuring the gases present in lunar orbit it is vital to achieve complete sterility from any induced gas clouds created by the natural venting cycles of the spacecraft. A mass spectrometer, carried by the service module on the 2 previous flights, could never quite achieve this remote sensing capability, always remaining in close proximity to the spacecraft. In an attempt to obtain a neutral background sample of the lunar 'atmosphere', namely potential atoms of helium, neon, argon, and krpton, a Lunar Atmosphere Composition Experiment, or LACE, was provided in the ALSEP package of Apollo 17.

Basically a Neir-type magnetic sector field mass spectrometer, the device collects gases through an inlet manifold, passing them through an electron beam ionising filament before convergence in a focusing assembly and passage through to a magnetic field. Here the circulatory motion of the particles enables measurement of the quantity, lense mass, and the number of stripped electrons. The spectrometer contains a layer of reflecting mirrors for thermal control and dust cover, removed by ground command after the crew left the surface, whereupon the entire assembly becomes active.

Volcanic emissions of carbon monoxide, hydrogen sulphide, ammonia, sulphur dioxide, argon and water vapour can also be detected. The instrument scans in 3 ranges of atomic mass units: 1-4, 12-48, and 40-110.

Following deployment of the LACE, Schmitt set about erecting the central station, a data collection and communications interface between ground and all four experiments, the HFE, LSPE, LACE, and a yet to be deployed Lunar Ejecta and Meteorites (LEAM) experiment, also relaying current from the SNAP-27 nuclear generator situated a few metres away.

The final ALSEP instrument was now set down on the valley floor of Taurus-Littrow, destined for a passive role to record the variations in dust rates, determine the ejecta events and general infall of fine particles on to the lunar surface. Called LEAM the instrument contained an upper and a lower sensing platform. A dust particle falling to the surface at speed would penetrate a grid and pass through an upper sheet of film, travelling down to repeat the process on a second grid/film combination. An electrical pulse created by puncture of the film above and below displays velocity, and the speed versus pulse strength indicates mass. The exposed area is divided into 256 sensors, all of which are grouped into 16 basic segments.

The LEAM stands on 4 legs, is levelled with the aid of

an attached gnomon and activated after the crew leave the Moon by detonation of a dust cover retention squib. Like the LACE the LEAM is only activated when the disturbances created by the presence of the astronauts have dissipated. The capabilities of the LEAM permit it to record particle velocities of 1 to 75 km/sec, energy ranges of 1 - 100 ergs and frequencies up to 100,000 impacts per square metre per sec.

Effort now turned to the remaining items to be deployed in support of the LSP experiment with erection of the remote antenna and lay-out of the 4 geophones.

All the while Cernan had busied himself with the HFE, and now he turned his efforts toward deep core drilling, finally emplacing a neutron flux probe. Stored in 2 1.23 metre long sections the probe was inserted into the deep drill hole and left there until retrieval on the third EVA. It consists of boron and a plastic interface brought together when the 2 sections of the pole-like device are joined. Neutrons interact with the boron producing α particles that scar visible tracks in the plastic. The experiment was designed to measure the capture rate of low energy cosmic rays and secondary neutrons, calibrating these as a function of depth beneath the lunar surface.

For some time during the ALSEP deployment Cernan experienced difficulty drilling through into the regolith and Schmitt was required to assist with extracting the stems by physically throwing his entire weight on to the jack.

At the conclusion of these tasks the 2 men, some time behind schedule, set up the LRV for their first geological traverse. They had originally intended to traverse across to a crater called Emory 2.4 km south east of the landing site but due to a 30 min over-run on time they were directed to Stenor, a crater only half way to Emory.

Passing Trident, a triple formation, they stopped some 1.2 km from the LM just short of Stenor, remaining there until 5½ hr. into the EVA. Back at the LM with 29 lb. of samples and an LRV with its rear mudguard broken, the 2 explorers set up the final experiment that would require their attention.

Destined for operation on EVA's 2 and 3 the Surface Electrical Properties experiment required the deployment of a device for transmitting radio waves through and along the lunar surface. The transmitter for SEP is a box structure on short legs, containing its own solar cell array for electrical power, and 4 deployable antennae 35 metres in length laid out on the lunar surface. Radio waves of 1, 2.1, 4, 8.1, 16 and 32.1 MH_Z are transmitted from this instrument to a remote receiver containing a tape recorder installed on the rear of the LRV.

The transmitter radiates energy in every direction and permits analysis of the subsurface layers, building up a profile of the regolith, its boulder content and the dispersion of materials of varying density.

EVA 1 lasted a full 7 hr. 12 min. and was terminated 33 minutes later than scheduled into the total stay time.

Second EVA

The second excursion began some 27 hr. 33 min. after touch-down, nearly 1½ hr. later than was originally scheduled. For nearly 1 hr. the crew prepared the LRV and performed a repair job on the mudguard. Their objective now was to traverse across to the light mantle beneath the South Massif and sample the area ground at the base of the mountain, moving north to stop at a crater called Shorty. It was here that the dark halo around the rim looked most like a volcanic vent, or fumarole, indicating that the crater could in fact be a natural vent.

Cernan and Schmitt departed in the LM at 53 min. into the EVA and spent the next 83 minutes rolling across the gentle undulations of the valley floor. The boulder population rose dramatically as the LRV wheeled its way across the light mantle, supposed deposits from the very peak of the South Massif. Finally, nearly 8 km out from their 4 legged home they came to a halt some 2¼ hr. into the EVA, just a little behind the timeline. For more than an hour they stayed in this area, moving downslope for additional sampling and displaying heart rates in the 90's.

The activities at station 2 required polarising photo's, rake and core samples, documented samples and panoramic photo's.

Less than 4 hr. into the EVA the crew had arrived at station 3, a region considerably downslope of station 2 and further north; but still 6 km distant from the LM. Driving between sites the astronauts were able to sample interesting areas without dismounting by using an LRV Rake Sampler. Looking somewhat like the rake used on-station the device cut down appreciably on the overhead time of this activity

Some 4½ hr. into the EVA, and 30 min. behind on time, Cernan and Schmitt, their vehicle laden with tongs, rakes, scoops, hammers, extension handles, drive tubes, gnomon, samplers, sample bags, core sample vacuum containers, environmental sample containers, cameras, lenses, magazines and containment bags, slowly bounced, rocked, and leapt their way north-east to station 4 – Shorty crater. They arrived at 4 hr. 47 min. into the EVA.

Within 5 min. Cernan had proclaimed the existence of 'orange' soil, and set the scene for one of the most exciting speculations of the mission. Had these two final explorers obtained proof of oxidised minerals, the existence of water, or the natural process of volcanism? The sulphur-like soil was collected and a drive tube confirmed that it existed to some depth. Meanwhile on Earth the science support room at Houston erupted into a frenzy of concentrated energy and anticipation, and soon the stay-time at Shorty had been extended. The camera on the LRV frantically scanned the surface for signs of the colouration but all to no avail. The hue was too narrow in the spectrum for resolution on the vidicon.

Finally, after nearly 45 min. at this stop the men departed almost due east for their final station – a 700 meter crater called Camelot. They spent about 30 min. here before moving back to the LM. After a record 7 hr. 37 min. the second EVA was over, the crew very tired, slightly exhausted but exuberant over their 'find' of orange coloured soil.

Third EVA

The third and final EVA began less than 1 hr. later than planned, some 50 hr. 30 min. into the 75 hr. 1 min. stay-time on the surface. Within 45 min. Cernan and Schmitt had started out for station 6, a region just beneath the impressive North Massif and marked by a double boulder visible in the Apollo 15 reconnaissance views. Thirty minutes later they arrived and for nearly 2 hr. remained here sampling the impressive boulders that towered above them. A crater called Henry gave slight relief to the blanket-like floor of the Taurus-Littrow valley, sparse on boulders, but over-populated with brecciated blocks on the low mountain slopes.

From here the explorers moved across to the Sultpured

Hills, then down to station 9 at 4 hr. 20 min. into the EVA, a crater that appeared similar to Shorty but no more orange coloured soil was found.

Deleting station 10 *en route* to 'Challenger' they arrived back some 5 hr. 45 min. into the EVA.

During the traverses across the surface a gravimeter had been carried for making localised measurements of the gravitational field, hopefully to assist in mapping the sub-surface in the valley area. The LSG adopts the principle of energy transference to show variations in attraction, in turn indicating the presence of a deep subfloor unit directly proportional to the increase on a milligal scale of measurement. High readings indicate deep units. The vibrating string accelerometer uses a mass suspended beneath 2 springs with determinations calculated electronically on the frequency variations of vibration. Mounted on the rear of the LRV the LSG was read from a coded scale at several points on the traverses.

Before departing the lunar surface for the last time Cernan de-activated the Surface Electrical Properties experiment and collected the cosmic ray detectors. These latter were slabs of mica, aluminium, glass, lexan, etc., contained on three 10 x 6 cm tags and hung on the exterior of the LM. Tiny tracks record the passage of cosmic rays and solar wind particles providing information on the type of particle and direction of travel.

Yet other tasks remained. Cernan began to describe to the watching TV camera how he wished the Apollo Programme to stand in the eyes of the youth of today. He said, 'The door is now cracked, but the promise of that future lies in the young people not just in America but the young people all over the world, learning to live and learning to work together'.

He went on to describe a rock, formed aeons ago and composed of many minerals and structures intermingled to form a single consolidated unit, '.......outlasting the nature of space, sort of living together in a very coherent, very peaceful manner. We hope that this will be a symbol of what our feelings are, and a symbol to mankind that we can live in peace and harmony in the future'.

Shortly after this he turned to a plaque attached to the forward strut of the LM and unveiled it to the TV camera. 'To commemorate not just Apollo 17's visit to the valley of Taurus-Littrow but as an everlasting commemoration of what the real meaning of Apollo is to the world, we'd like to uncover a plaque that has been on the leg of our spacecraft that we have climbed down many times over the last 3 days. And I'll read what that plaque says to you.

'First of all it has a picture of the world – two pictures – one of the North America and one of the South America, the other covers the other half of the world including Africa, Asia, Europe, Australia and including the North Pole and the South Pole. In between these 2 hemispheres we have a pictorial view of where all the Apollo landings have been made, so that when this plaque is seen again by others who come they will know where it all started.

The words are 'Here man completed his first exploration of the Moon, December 1972 A.D. May the spirit of peace in which we came be reflected in the lives of all mankind'. It's signed Eugene A. Cernan, Ronald E. Evans, Harrison A. Schmitt and most prominently Richard M. Nixon, President of the United States of America. This is our commemoration that will be here until someone like us, 'till some of you who are out there who are the promise of the future come back to read it again and to further the exploration and the meaning of Apollo'.

Then Dr. Fletcher, Administrator of NASA, joined the capsule communicator Bob Parker at his console and spoke to the 2 astronauts on the lunar surface. 'Gene and Jack, I've been in close touch with the White House and the President has been following very closely your absolutely fascinating work up there. He'd like to wish you God speed as you return to Earth and I'd like to personally second that. Congratulations! We'll see you in a few days'.

Cernan replied (both of them visible standing close to the rover by the forward landing strut): 'Thank you Dr. Fletcher, we appreciate your comments and we certainly appreciate those of the President, and whether we be civilian or military I think Jack and I would both like to give our salute to America. And Dr. Fletcher if I may I'd like to remind everybody I'm sure of something they're aware that this valley, this valley of history has seen man complete his first evolutionary steps into the Universe'.

After driving the LRV several hundred metres, due east from the LM Cernan returned to assist Schmitt with packing away the neutron flux probe that had been deposited in the deep drill hole on EVA-1.

With all the bags, film magazines, and equipment packed aboard the LM Cernan approached the ladder of Challenger with these words: 'Bob this is Gene and I'm on the surface and as I take man's last step from the surface back home for some time to come, but we believe not too long in our future, I'd like to just leave what I believe history will record: That challenge of today has forged man's destiny of tomorrow. And as we leave the Moon and Taurus-Littrow we leave as we came and God willing as we shall return, with peace and hope for all mankind. God speed the crew of Apollo 17. Bob, I'm up on the ladder and I'm going to be going through the hatch'. Thus, for the last time did a human being step aboard his tiny vehicle, leaving behind a ten million year long reminder of his first uncertain journeys across the surface of the Moon.

The third EVA had lasted just 7 hr. 16 min, and all 3 had set a record 22 hr. 5 min. for 'Challenger'. The 2 astronauts had journeyed farther from thier base than ever before, and the total distance travelled, 35.8 km, was 8.1 km more than achieved by Apollo 15.

A sleep period lay ahead and two further depressurisations for jettisoning equipment now redundant and likely to present a hazard by narrowing the weight safety margins. Among equipment left on the surface was a group of items deposited for subsequent retrieval, possibly decades hence, when the second-generation manned lunar vehicles roam the Moon.

Throughout the 75 hr. stay the performance of the 'Challenger', support equipment, experiments, and crew had, with few exceptions, been impeccable. The lift-off came as a splendid climax to 3 memorable days of exploration. With the words,'Take your final look at the valley of Taurus-Littrow', Cernan gave the computer an instruction to proceed and seconds later the ascent stage rose swiftly on its way to a 10.4 x 55 ml orbit.

As the 2 vehicles disappeared around the western limb of the Moon final computations were being made for Terminal Phase Initiation, the final stage toward rendezvous. Coming around the eastern limb the 2 vehicles approached each other to achieve a docking on the 3rd attempt little more than 2 hours after lift-off. The wanderer had returned.

To be concluded]

A EUROPEAN SPACE AGENCY

By Kenneth W. Gatland

Introduction

The 11th hour call by Mr. Michael Heseltine, the UK Minister of Aerospace and Shipping, for a European space agency to co-ordinate and manage European space effort, including the response to America's post-Apollo invitation, has been widely welcomed, though it has taken Ministers long enough to awaken from their slumbers. Indeed, there are those who would be churlish enough to suggest that Britain should look to her own piecemeal approach to space organisation and do something to unify space interests at present scattered throughout Whitehall and beyond, namely in the Department of Trade and Industry, Ministry of Defence, Department of Education and Science, Post Office, Ministry of Posts and Telecommunications, Meteorological Office, etc., (see 'The Urgent Need for a UK Space Authority', *Spaceflight* January 1973, pp. 33-35).

Wasted Opportunities

For more than a decade the absence of central management has frustrated the development of a common European space policy and is at least partly responsible for the 'Tower of Babel' image that European Space has acquired. The same neglect has effectively blunted any chance we may have had of major contributions to the high technology of post-Apollo. A more professional management structure, for example, might have won for European industry a place in designing and developing the fly-back space shuttle to which we contributed in Phase B studies. Lack of political cohesion, not technical ability, was a major factor in losing us the opportunity to work on this advanced space project which is bound to produce a major spin-off to general aviation, which now becomes an American monopoly.

One recognises that there exists an alternative view, that the United States wishes to hold the reins of all major space technology; but all the same where there is a lack of confidence in management machinery it is very difficult to set up major collaborative projects which have to be developed according to rigid timetables and within strict cost ceilings.

Long-standing neglect of central management in European space affairs has been questioned repeatedly by the Council of the British Interplanetary Society, and the theme has been echoed by other bodies including the Air Research Council, the National Industrial Space Committee and Eurospace. The matter has also been raised in the Council of Europe.

B.I.S. Initiative

After recommending to the Macmillan Government in February 1960 a plan for the future development of European and Commonwealth space research and technology, including scientific and applications satellites, the British Interplanetary Society first took up the question of space programme management in Recommendations to the Wilson Government in April 1965.

Part of this document read:

'Careful consideration should be given to the organisation of an active space programme, both in the United Kingdom and Western Europe. In neither case, at the present time, is there a central body to co-ordinate all aspects of a space programme.

To rectify this situation it is necessary that there should be a single UK Authority dealing with all aspects of space research and technology. On the Western European scale, the British Government should press for a corresponding co-ordinating space authority'.

'The efficient use of financial and technical resources', it was stated, 'requires the establishment of a single Western European Space Authority which clearly defined goals and terms of reference'.

Slowly, the general idea of a more efficient administrative machinery for Europe's fragmented space programmes received Ministerial consideration:

July 1966	Ministers of ELDO countries consider the general co-ordination of Europe's space activities, the proposal being to combine activities of ESRO, ELDO and CETS.
July 1967	Ministers decide to 'formalise' the European Space Conference as a body meeting regularly to elaborate a co-ordinated European space policy and to supervise its execution.
November 1968	European Space Conference agrees in principle on the desirability of merging the existing European space organisations, and sets up a Committee of Senior Officials to work out the procedure and draft a convention for a united organisation.

Post-Apollo Concern

The absence of any significant move by governments to implement proposals for a European space agency – especially in the light of negotiations with the United States on post-Apollo participation – caused the B.I.S. Council once again to stress the urgency of taking some initiative.

In Recommendations to the Heath Government on 1 February 1972, the Society urged:

'European initiative, with immediate action to strengthen European space management by merging ELDO and ESRO into a single European Space Authority. This body to be given full authority to negotiate terms for a viable international programme, initially with the National Aeronautics and Space Administration, within the context of the approved post-Apollo programme.......'

On 8 November 1972 in Paris, Mr. Heseltine placed before a meeting of European Ministers the idea of a European space agency to which all participating countries would be free to contribute to selected projects, including the post-Apollo Sortie Lab., choosing their own level of financial support.

After the European Space Conference on 20 December, the text of the following Resolution was issued in Brussels:

'The European Space Conference agrees:

1. A new organisation is to be formed out of ELDO and ESRO (European Space Agency) if possible by 1 Jan. 1974.
2. It shall be the aim to integrate the European national space programmes into a European space programme as far and as fast as reasonably possible.
3. The European Space Conference gives general approval for the following projects to be carried out and managed within a common European framework:

   Post Apollo (Sortie Lab);
   The French launcher proposal, whereby EUROPA III is being dropped;

   The question of participation and financial contributions will be decided later by each country.
4. There should be a rationalisation of the various satellite programmes including GTS on the understanding that the agreement of 1971 in ESRO is not being questioned.'

Subsequently, it was disclosed that the Post-Apollo Sortie Laboratory was being supported immediately by West Germany and Italy, who were expected to bear the main burden of costs. The UK Government was prepared to spend no more on civil space than it was already doing. However, if others shared UK projects (e.g. a 20-40% contribution to the Geostationary Technology Satellite) there could be diversion of funds elsewhere (e.g. to Sortie Lab).

The French launcher proposal has not received wide support and the final outcome is uncertain. The L-3S concept put up by the Centre National d'Etudes Spatiale (CNES) and Direction Techniques des Engins (DTEN) was as follows:

Stage 1 Virtually the Europa 3 first stage, designated L-150, with 4 LRBA Viking 2 engines of 60 tonnes thrust each. Propellents UDMH/N_2O_4.

Stage 2 New stage concept designated L-30 with single Viking 2 engine. Propellents UDMH/N_2O_4.

Stage 3 Cryogenic stage designated H-6, with single HM-4 engine of 6 tonnes thrust.

France was reported to be ready to invest at least £114 million in L-3S. Full development costs over 8 years were estimated at around £190 million. Object is to achieve the full performance capability of Europa 3, i.e. 750 kg into geo-stationary orbit.

SPACE COMMUNICATIONS FOR EDUCATION PURPOSES

This symposium, which marks a new departure in the activities of the B.I.S, was set up as an extension of the 2-day meeting on 'Communications Satellites' held the University of Southampton on 19-20 September 1972. The participants included a number of leading educationalists, both UK and continental European, as well as interested members of the Society, the total attendance being about 25. The objective of the meeting was an exchange and co-ordination of views between those practised in education and in space communications to lead, if generally felt desirable, to a joint study group to promote this application as an on-going activity. In the unfortunate absence of the President owing to illness, the Chair was taken by Dr. N. Simmons. Contributions were read as follows:

Mr. M. Edmundson (HM Inspector, DES) – *'Space Communications and Education'.* In this introductory paper, Mr. Edmundson referred to the recently-concluded Council of Europe study, from his viewpoint on the Steering Group. While primarily directed to higher education, this was comprehensive enough to have implications for all levels of education; pre-school, school, education for leisure, retirement, re-training, etc.It foresaw a revolution in education in Europe, embracing resources, apparatus and access: satellites could be part of this concept. It was clear that these services would greatly expand in the next decade and one particularly important concept was that of an European Institute linking all universities and research centres. However, this expansion was severely limited on existing terrestrial broadcast systems – the pressure was being felt already – and extension of these facilities would be very expensive.

Dr. J. L. Jankovich (Consultant to the Council for Cultural Co-operation) – *'Satellite Services for Education and Culture'.* In his first paper, Dr. Jankovich summarised the findings of the Council of Europe study, which he had carried out. This had made a quantitative estimate of the communications traffic necessitated by the rapidly increasing demand for all types of higher education, a demand that the universities could not hope to meet by traditional methods. There would be a need for a complete network linking European universities. Terrestrial links, point-to-point satellites and broadcasting satellites, of the semi-direct type, could all find a place in meeting a demand that would, for education alone, arrive at a level exceeding the general TV provisions at present in existence in Europe. Dr. Jankovich's second contribution – *'Are Satellites really needed for European Education?'* summarised the systems analysis approach. This had shown that satellites offered cost advantages. There was an urgent situation and a need for initiatives by educationalists towards policy-makers. There should be European collaboration and an experimental phase should provide the necessary feed-back into educational practice.

Mr. Whitaker (Head of Educational Television Unit, Birmingham University) gave a brief expose on a wide-ranging study that he had carried out for the National Council for Educational Technology of the potential of all existing video systems, including even fibre optics. A full report is to be published by the NCET.

Dr. M. Schmidbauer (Int. Zent. f. Jug-Bildung) – *'Educational Satellites for Developing Countries'.* The Speaker referred to the vast need in the new countries where the number of illiterates is actually increasing. This involved the problem of training sufficient teachers. To overcome the crisis, the traditional method would be far too slow, taking perhaps 30 to 45 years for system planning and implementation, whereas only 7 - 10 years would be required by satellites. Many countries had no other choice. Satellites would be more flexible and present also the advantages of response to shifting communications demands, international co-operation, etc.

Dr. W. de Vogel (Scientific Director, Stichting Film en Wetenschap, Netherlands) – *'Experiments with Microwave Links between Universities in the Netherlands by PTT Systems and the Future Use of Terminals in this System'.* This paper set out the revolution in teaching methods that will come from the full application of modern communications technology, in particular the use of TV as a primary audio-visual tool. Dr. de Vogel explained the role of the 'video centre' in a future school or university as it will be imaginatively integrated into the instructional process and described his own establishment, which is pioneering this technique.

Mr. G. K. C. Pardoe (Hawker Siddeley Dynamics) – *'The Prospects for Educational Services by Satellite'.* Mr. Pardoe gave a general review of the studies and projects that have been undertaken throughout the world, with particular mention of the UNESCO project in South America and stressing the problems of soft-ware.

Dr. N. Simmons, (MOD Procurement Executive) – *'Space: Technological Aspects of Educational TV'.* This paper demonstrated the difficulties that would be found in attempting to extend the existing terrestrial networks to meet any greatly increased demand for TV channels and outlined, mainly for the benefit of educationalists, the leading features of the alternative satellite systems. The technical way was now open for procurement of such systems and the burden of an initiative now rested with those who would require a service.

Following these presentations, the meeting entered upon a round table discussion of what should now be done by the European community, with the following general conclusions:–

(1) On the moral issue of whether a primary emphasis should be given to developments in Europe or in the developing countries, it was generally felt that these objectives were not in conflict. Indeed, both types of activity had already made an effective start and work done on a European system would provide a system capability for elsewhere.

(2) The scale of the demand suggested by the Council of Europe was surprisingly large and its validity would need to be verified. In any case, the approach should be tentative and evolutionary, though delay is not warrented. It may be valuable to extend the Netherlands experiment to a European basis. The educational demand should be fed into the recent CEPT economic assessment of intra-European telephony circa 1980-1990, where it would have a profound effect. Technical studies would be required to see whether by any means (e.g., 'slide projection') the data capacity required for ETV could be materially reduced.

(3) There was need for an on-going activity to bring before the authorities, both European and national, the urgency and importance of the problem now facing the educational community and to undertake studies clarifying the points mentioned above. The meeting agreed that the B.I.S, with the collaboration of educationalists, could provide a suitable unofficial forum within the UK and an informal working group should be established with participation of volunteers willing to give their time. The B.I.S. would inform its sister societies in Europe, at the forthcoming IAF conference, of what is planned to do and suggest that they undertake parallel action. There could then be interchanges on the annual occasions when these societies meet together (IAF and European Space Symposia) and at other times they could remain in postal contact. Contact would also be made with the OECD Working Party on Educational Technology and, meantime, Mr. Edmundson would report the outcome of the symposia to the Council of Europe committee, which had asked for this action. Participants in the symposium would be invited, if they so wish, to join the B.I.S. study group, which would decide after further discussion its own programme of work.

EDUCATIONAL SERVICES BY SATELLITE*

By G. K. C. Pardoe and S. E. Wythe†

Introduction

In looking at the prospects for Educational Satellite services it is worth noting at the outset that technological levels are not the limiting factor on the development of an Educational Satellite System. Accepted limitations are essentially economic and political. The development of an Education Satellite System gives no guarantee that it will be used effectively. The problem is not hardware design. The real barriers are typically:

using technology to meet real needs;
obtaining spectrum space for an educational service;
provision of effective software;
obtaining support from teachers and educational community for use of such;
technology;
training of teachers and others to use the technology;
guarantees to educators of free and unlimited access to ground facilities;
maintenance of free flow of information between countries;
the overcoming of language and cultural barriers;
solving of time zone problems and of real time communication; and
resolve copyright policies to the benefit of both writer and reader giving protection and freedom.

Principles and Objectives

The introduction of an Education Satellite System was first discussed in UNESCO in 1960. A continuing dialogue has been pursued since that date. There would appear to be a a need for educational systems with link-ups on national, regional and international levels and the need extends across the spectrum of developed, developing and under-developed nations in all spheres of education from pre-school, primary and secondary to higher and adult levels. The requirement is greatest where the living standards are lowest, when it is calculated that the results will be a quantum step in the improvement of the standard of living.

The techniques recommended place the use of TV first, with radio as a back-up on introductory systems. Support to be obtained by using ancillary assets such as cassettes – video and audio – tapes – films – facsimile and computers. Satellites are accepted as the most effective means of applying TV in either a unique or hybrid manner, the latter being supplemented by microwave, cable and landline networks. The form of transmission and reception can vary, the limiting or deciding factor being the economic situation of the recipient and the subsequent provision of ground receiving equipment. The provision and costing of the system is well defined in the hardware segment and is accepted as an established (decision making only) fact. Programme derivation, methods of putting over, standards of instruction, in other words, software, presents problems especially in the under-developed countries. Here much planning and definition remains to be undertaken.

In discussing the educational use of satellites it is inevitable that the talk is of international co-operation and the international sharing of teaching resources. Invariably these are contentious points and studies and research has been undertaken to show advantages associated with such proposals. Briefly these are:

Space communication will enable educational programmes to be given over a greater range in a quicker time and especially to remote areas.
Removal of rural and urban differentials.
Satellite based techniques allow for the low level of teacher training and mounting illiteracy by introducing flexibility of instruction.
It is economic if given to large audiences.
Regional systems are most advantageous and economic, individual and national schemes at present are uneconomic.
Unique Educational Satellite Systems are thought to be the best method – multi-purpose satellites are not really satisfactory.
With co-operation on both international and regional levels the administrative and legal machinery should be

* *Paper presented at the B.I.S. meeting on 'Space Communications Systems for Education Purposes', Southampton, 21 September 1972.*

† *Hawker-Siddeley Dynamics, Stevenage, Herts.*

straightforward.
Space satellites are both stimulatory and catalytic because they infuse new techniques and reform in education.

Principles advocated for the successful introduction of an Education Satellite System are suggested as:

1. The programme content is really a question of insuring that there is something worthwhile communicating, i.e. software.
2. Teachers, broadcasters and technicians must be trained to use TV efficiently and effectively as an educational tool.
3. Political accord is a necessity with the cultural and sovereignty of individual states being respected.
4. The application of the system and the flow of information will not be possible until the satellite system is able to feed visual messages to individual receivers capable of recording and storing.

Educational messages would cover:

Point to point link-ups between universities, forums and research, directly linking centres of advanced knowledge.
Allow relay of data.
Open universities – TV courses – telex – correspondence and other feedback techniques.
Computer assisted programmed instruction.
Facsimile reproduction of printed material for instructional purposes.
Use as electronics blackboard.
Instructional programmes for all levels of school students (can be recorded and used in curricula).
Adult programmes for social – civil – health – agriculture – family planning – home economics.
Teaching of literacy.
Vocational training.
Training and improving levels of competence in teachers.
Limitations are regarded as economic and political, the costs of international educational systems using satellites are calculated as quite trivial compared with long term benefit. Hardware costs could be in the order of $1 per year of student population in developing countries. On this planet there are one billion children of school age, but the number of people who require education is even higher. TV, being visual, could quickly transcend this problem. The language barrier would be removed with visual application.

Current Interest and Prospects

Interest in the development of Educational Satellite Systems has been widespread. Basically, studies are concentrated among the developed countries of both West and East, with growing levels of interests in the developing nations.

USA

Not unnaturally, extensive promotional activities are being conducted in the USA with internal and external connotations.

At the Universities of Washington and Wisconsin investigations have been carried out on the application and use of Communication Satellites to help meet the educational needs of the USA and the provision of a Multipurpose Satellite educational service. In Washington a small number of alternative satellite systems have been analysed alongside USA educational needs, noting the fresh appraisal of education now under way within the American Continent. They advocate the use of Education TV Satellites alongside cable TV – cassette – disc video – microfische – and computers. The costs of education in general, satellites augmented with these other electronic aids, are assessed as giving the best value. The Education Satellite Centre, Wisconsin, established to foster use of satellites for education, recommends that a full TV satellite can provide a variety of services into schools, using video tapes – tape recorders – filmshows – telelectures – radio – facsimile – computers. The potential is currently extensive within the USA for the shared use of ground based receiving centres to handle digital processing, storage and time sharing.

Europe

Here, it is a case of satellite communications representing a solution looking for a problem. The Council of Europe had initiated studies to define educational problems to see if remedies are possible.

The subsequent investigation covered 17 countries and confined itself to higher education. It set out to define higher educational needs, telecommunications in general and satellite communication services in particular, to help the P.T.T's to formulate a co-ordinated position in I.T.U. and develop the framework of future investigative methods to help European educational systems. The study established certain points in the communication envelope:

TV is one method, but not necessarily the best.
Teachers are the focal point of any system.
Three basic types of telecommunication:

point to point – wideband between institutions (selective).
broadcast of audio and visual to public.
point to point two-way audio/visual-individual and educational sources.

The bandwidth requirement is substantial and may be as large as that envisaged for the communication system for Europe in the 1980's.
Will be cost-effective if hybrid (satellites + terrestrial).
Terrestrial for close links and to carry heavy traffic;
Satellite for less dense traffic and widely spaced locations.
Broadcast on semi-direct bases via satellite to community receivers through prepared newly opened channels.
Two-way cable links from centres to universities linked in turn by satellite.
Comparison of estimates on costs of terrestrial only and hybrid system show a saving if using hybrid over 15 years sufficient to finance development of a satellite and launcher.

Conclusions were that no satellite will be needed if traditional teaching methods are continued and expanded in future. If not, then the situation would become hard pressed and not meet demands unless new technologies are used, utilising terrestrial and satellite systems. Satellite requirements include distribution method (P-P) with

multiple access plus demand assignment. This would involve semi-direct broadcasts to community receivers wired to home receivers.

South America

South America suffers from deficient industrialisation, plus an education system inadequate and unadapted to meet the needs of the new modern world. What there is costs four times what it should! A TV system would be an economic means of transmitting and distributing information which would help solve social problems and educational needs.

The technological capability of satellite systems to help provide this service is accepted. An economic assessment indicates that the cost is comparatively low. Student population will be 60-70 million by 1980, nearer 100 million if all the educationally deprived were included. Calculations show it feasible to expect one TV set to serve 80 students on a 2-3 shift basis, giving a requirement 1,250,000 TV sets, rising to 1.5 million if all considered, plus two transmitting stations and studios and satellite(s), one with 10-12 channels or two with 6-8 channels.

Typical example of costs	$	$ (million)
Direct receivers	350 each x 500,000 =	280
Conventional receivers	100 each x 700,000 =	70
Rx/Tx stations	- - =	30
Tx stations + studios	10 mil. x 2 =	20
(Satellites	10 mil. x 3 =	30
(Launcher	10 mil. x 2 =	20
	Total	450

Gross cost per student	$	$ (m/yr)
Ground segment	400 million @ 10 yr.	40
Space segment	50 million @ 7 yr.	7
Maintenance 10% per yr.		40
Production & transmission		20
		107

100 million student @ 107 m/yr	= $1 per head per yr
100 million student other costs (electricity)	= $1 " " "
Written support material	= $1 " " "
Course material	= $2 " " "
Grand Total	$5 " " "

Summary

100 million students @ $5 per head per year	= $500 mil.per yr.
Plus current educational costs	= $2000 " "
	$2500 " "

Current spend is 2.68% of GNP as compared with 5% of GNP in USA.

Regional system for South America

In 1970 UNESCO proposed a regional system for Latin America to ensure fast qualitative and quantitative improvements of educational and cultural levels in all parts of Spanish-speaking South America.Implicit in the proposal was the introduction of a TV service supplemented by cassettes, films – radio – video tape. The directive was to maximise the potential of both hard and software. Thus educational TV is expected to have a spin-off effect on non-TV educational areas.

Qualitative improvements are expected to manifest themselves as TV is looked upon as the fastest method of improving the situation, and has the capability of largest coverage and pedagogical impact (on thousands of students and teachers). Failure will only occur if there is a lack of impact due to lack of genuine demand. It must therefore be relevant overall and take into account contraversial issues. Coverage must be maximum at all levels across the educational spectrum and contact must be extensive. In South America education is both good and bad, being academic without recognising the human and pragmatic outlook. Educational TV can provide three times the normal method with a flexible service available to all students. Availability criteria is for 4 channels 365 days per year. In fact, it will be 200 days with the intention to expand into holidays and be repetitive in approach. It aims to provide 4 programmes simultaneously 17 hours per day in 20 minute packages. Transition period is to be 1975 - 1989.

Agreement was signed between Latin American countries early in 1972 and a team of UNESCO experts are currently active. The terms of reference are to relate the cost effectiveness of a satellite *vis-a-vis* microwave network and determine where and how direct broadcasting might be preferable to a distribution system taking into account demographic considerations. Their findings might be used elsewhere in the world. The educational TV service will serve countries bordering the Andes and include Paraguay and Uraguay. The two-year delay in commencing the study was due to political considerations plus commercial opposition from companies with microwave vested interests.

Brazil is actively developing a domestic satellite system to become operational in 1975/76. From the middle of 1973 she intends to have a transponder on board an Intelsat 4 stationed over the Atlantic, for an intervening period of 2½ years. This interim arrangement plus the domestic satellite would provide broadcasting and telecommunication facilities. Emphasis will initially be on a TV service to remote and isolated districts using low powered re-broadcast stations.

Canada

Canada is committed to a domestic satellite system to provide broad band communication capability between States especially in its remote and sparsely populated northern territories. It will be providing a TV service (implying educational opportunities) financed by Government and private capital with an operational date of 1973. A broadcast service will be provided using ground facilities reputed to cost less than $20,000 each.

Potential African

These educational systems are linked with France and UNESCO. French space research has been examining the relative merits of some application of the Symphonie satellite,

as opposed to microwave networks, for distribution of educational services in French-speaking African countries. Currently, no positive comment or response has been made. The African Broadcasting Union, however, has invited a team of UNESCO experts to conduct a preliminary study to sign-post how an educational TV system might be introduced in terms of cost effectiveness and overall efficiency. Factors to be noted include population patterns, language distribution and the varying educational needs of the different countries. The study is aimed at enlightening governments on the potentialities of space communication and its implementation. To eliminate options would be regarded as progress. Finance is a problem requiring more than African finance alone. At present regional systems are considered more beneficial than continental or a series of national systems.

India

Perhaps the best known hard project to provide an educational service is that of India. A pilot scheme had been defined whereby NASA would provide partial use of ATS-F for 1 year to provide 4 hours per day broadcasting to selected parts of the Indian continent. A mixed broadcast and direct service is envisaged with when 5000 TV sets, 2000 to receive directly from the satellite. This scheme will lead directly to the development of an Indian domestic satellite system planned for the late 1970's. Unfortunately, due to technical and design modifications, the ATS-F programme is now one year behind schedule. Coupled with this delay is a growing move in the USA advocating that internal requirements should take precedence over India's request. It may well be that the provision of a direct broadcasting service to the Rocky Mountains, and Alaska, takes preference to re-positioning ATS-F over Africa for Indian usage.

Alaskan Education Satellite Project

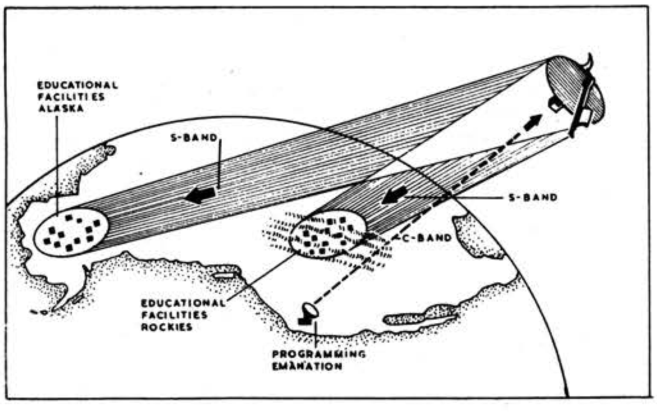
A pilot scheme was proposed in 1969 to transmit two-way radio programmes via satellites to three remote native villages, the programme to meet the needs of teachers in isolation. The scheme was proposed by the National Education Association in conjunction with the Alaskan Educational Broadcasting Company. Eventually, it was recommended via UNESCO that a radio but not TV service be provided, but not until ATS-F/G are available in 1973 using 2500 MHz band. Costs of the Ground Terminal using ATS-1 would be $20,000 each whereas a terminal receiver using ATS-F/G should reduce to $500-1000 each. Initial service to 20 villages incorporating 'Sesame' type programmes in lieu of TV video and audio tape is proposed, the reception to be on full and half-time basis.

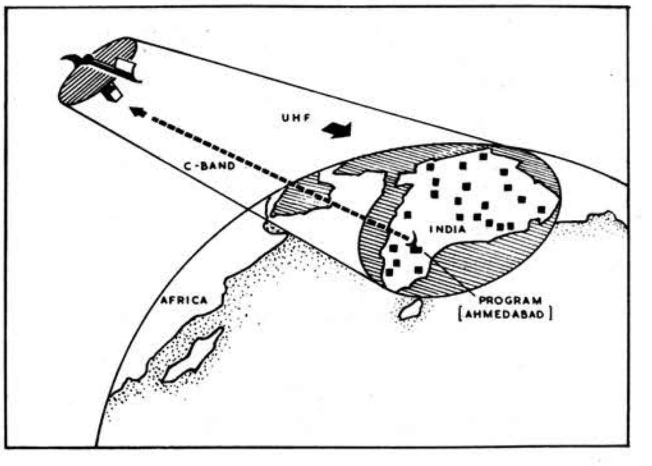
Far West teacher educational experiments on ATS-G

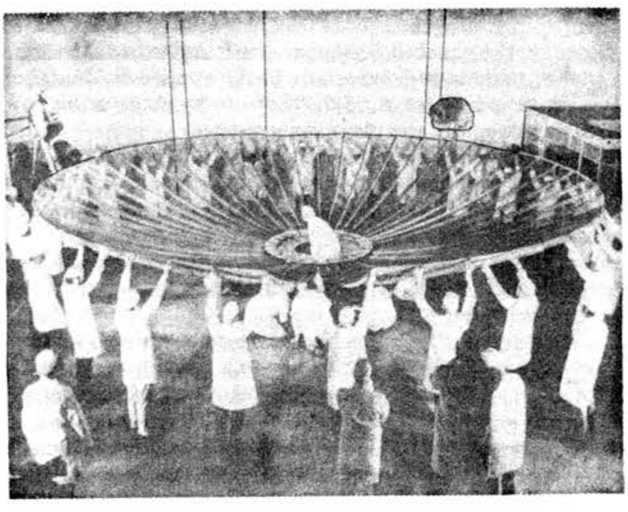
Advocated to expand professional development opportunities for teachers in sparsely populated areas on a continuing basis when teachers would benefit from watching good teaching in action. Proposal was for a 1½ hr. TV course at primary and secondary levels every Thursday for 60 weeks. Fourty-four community reception centres plus 6 community receivers would relay on C.A. TV lines. Telecasts would encourage discussion, and two-way voice communication will be established with centres and other teachers in reception areas, based at Billington in Montana, and covering an area

EDUCATIONAL TV. *Below, left,* ETV. ATS-F will beam Educational TV programming direct to unique, low-cost receiving stations located in or near schools or community centres in isolated regions of Alaska and the Rocky Mountains where terrestrial TV coverage is not feasible. ETV transmission will utilize S-band frequency and localise one-degree beam-width spot beams. The Department of Health, Education, and Welfare and the Corporation for Public Broadcasting are co-operating with NASA in this experiment. *Right,* ITV. The Governments of India and the United States are co-operating in the Instructional TV experiment. After ATS-F has been in orbit for one year, the spacecraft will be moved from its original position at 94° West longitude to 35° East longitude. Thrusters located on the truss structure will propel it to a new location at a rate of 45 ft/sec. There it will transmit instructional material designed to improve occupational skills, increase food production, assist in family planning, improve health and hygiene and train teachers. A ground station at Ahmedabad, India, will transmit programmes at C-band to ATS-F, which will relay video and voice signals via UHF to a network of some 3,000 inexpensive community receivers in rural and remote villages.

Fairchild Industries







Wrapping up the 30 ft. diameter dish antenna being developed for the ATS-F/G satellites. With each man at the periphery holding 2 ribs, the fine mesh antenna is 'walked around' a step at a time until it is tightly coiled round the hub.

Fairchild Industries

of 200,000 sq. miles. Transmission would be either from Mojave or Rosman (NASA). The system may eventually link with Alaska.

Pan Pacific

A proposal by Hawaii University with NASA approval that up to 15 universities in the Pacific basin, including Alaska, should be interconnected via satellite (ATS-1) on a point-to-point closed circuit communication system for regular 2-way voice data and facsimile transmissions. It will provide an international laboratory to undertake experiments and development activity in the use of telecommunication interconnection by satellite. Costs are regarded as manageable, most equipment being self-modified. There will be no language barrier, English being predominant. Time zone is reasonable with the 4-hour working day and the new 8 hr. educational day.

Conclusions

Improving educational services have always been conducted across the whole range of educational levels, perhaps with greater emphasis in the developed countries of the world. The advent of improved communication techniques has enhanced this activity and with the technological improvements assuming international emphasis, so has the ambition for improved educational services extended internationally. Invariably, education is viewed in a social context focussing attention on the educational differential existing between the developed and under-developed countries. Many studies have been undertaken with the objective of reducing this difference. Almost all review the available technologies and almost all conclude that the best method of solving this problem requires the introduction of the TV media applied through the use of satellites.

Conversely, these technologies are accepted as accomplished technical feats and are not regarded as a limiting factor. Limitations however, occur in the areas of economics and politics. Economic restrictions can be solved, it is suggested through regional or some form of international co-operation. Political problems still require agreement and accord.

In discussing the educational use of satellites almost inevitably the question is raised of international/regional co-operation especially in regard to the sharing of teaching sources. Cultural differences have become one of the major areas of restraint. Technical ancillary supporting techniques such as video tape standards, international radio/television circuits, are capable of reasonably rapid determination; programmes with culture and language differences seem virtually incapable of solution. Fortunately, an area where requirement and definition seem most likely to reach agreement is that of higher education. Here there are opportunities for the initial development of one form of educational TV satellite system. Perhaps with agreement possible at these higher levels of man's activity, there is hope for agreement at more mundane levels where the potential benefits are certainly greater.

SPACE COMMUNICATIONS AND EDUCATION*

By M. Edmundson

Introduction

Three years ago the Council of Europe convened a group to consider the implications of satellite services for education. From this, Dr. Jankovich was commissioned to carry out a study into the requirements of European Higher Education for Telecommunication Facilities and for Satellite Communications, and his researches and subsequent report were prepared under the guidance of a steering committee on which I had the privelege to sit. The report appeared in the spring of 1971, firstly in the form of a summary report for 'early-warning' to Goverments and later that year, the full report was published.

A limited budget restricted the study to Higher Education, but the implications for other levels of the educational system are clear enough and indeed, it is important to enlarge the scope of one's thinking to embrace 'education' as a whole.

Ostensibly, the fundamental purpose of the study was to advise Goverment representatives and to help prepare and co-ordinate claims for the needs of educational services at the World Radio Administrative Conference in the summer

* *Paper presented at the Symposium of the British Interplanetary Society on 'Space Communications Systems for Education Purposes'. Southampton University 21 September 1972.*

of 1971. But a second outcome is also discernable, and I quote from the summary report in the words of its author: 'The study represents the first modest step towards the systematic indentification of the fields and methods through which advanced technology can help European education and culture'.

I have always held the view that this second objective was more important than the first, and this view is supported by discussions I occasionally had with officers from M.P.T. and others. The conference has met. As I understand it, frequency bands have been allocated around 12GHz but assignments of frequencies for specific purposes is yet to come and is largely an internal matter for each country. *Now* therefore, is the time when the most careful examination is required for future educational requirements of broadcast services so that education will have a reasonable, carefully argued case on which if need be, it may build a claim to share the satellite service.

I hold, therefore, that the report has not yet been adequately discussed by relevant experts within the Council of Europe or in member countries and consequently not enough value has been obtained from it to justify the investment which was put into it in terms of money and time.

Channels of Communication

Channels of communication represent the vascular structure of an educational system. They range from the didactic instruction in the familiar teacher/class situation, to almost totally individualised learning such as may be true of a student of the Open University. Neither the teacher nor the learner who seeks information from external sources is particularly interested in how that information reaches him. This being so, I find the arguments for the use of satellites in the service of education are only peripheral when relating to any unique property that satellites may have, e.g. immediacy There are exceptions to this, e.g. if and when satellites are used in the link between students and the central data store perhaps of a European centre, or library, then rapid access and retrieval is essential to the process. But at the moment, and in the average learning situation, the weight of argument for satellites rests, by and large, with questions of capacity and demand.

The issues involved can thus be divided into two very broad areas for consideration. This is an over-simplification I know, but useful for the purpose of this introduction. The two issues are these: (1) Problems of feasibility, and (2) Problems of demand and capacity of channels of communication.

The report identifies 3 major feasibility criteria:

a) Technical feasibility
b) Operational feasibility
c) Economic feasibility.

The last – economic feasibility – is probably the hardest to analyse. I am led to believe that in industry, judgements are scientifically made after due consideration of the economic implications of alternative systems. But human societies and the goverments who rule them, rarely follow such clear-cut paths, strewn as they are with political and other obstacles. Even so, good advice, based on a sound investigation of all the variables, is still fundamental to decision making.

A worse danger in these advanced, esoteric fields, is that the evidence, the capabilities and so forth are not adequately discussed or understood, especially in the applied fields – such as education – for good decisions to be made or be made early enough in the planning sequence.

Many of these arguments apply also to a second set of problems, viz: problems of future channel capacity and how it will match up to future demand. There are experts among us who will know of techniques of improved terrestrial communication of which I have not yet heard. The place of the satellite will have to be found within this fluid ever-advancing technology.

The current trend in our schools and colleges, is to throw more of the responsibility for learning on to the pupil himself. To provide opportunity for the individual, either alone or in a small group to enquire, to search out, to explore on his own initiative. This does not replace the more traditional pupil-teacher relationship but supplements and enriches it. Its consequences are many: e.g. a new approach must be made to the management and organisation of the institute – school, college, etc. ; the need arises for a more complex resource centre within it, i.e., more books, perhaps copies of archive material, means of making quick copies of selected references, recorded material on disc, tape, slides and film. The need for access to material beyond the walls of the centre becomes apparent; material which has taken very many hours of research and preparation in institute 'A' should, in theory, be accessible to institute 'B'. These are just a few small examples of the increase in demand for new channels and new techniques of communication.

Pressures are growing in education in areas given little thought even 10 years ago: the pre-school years of 2-5; continuing education and re-training throughout life (the James proposals of in-service training of teachers is a good example!), and education for leisure, for retirement, and so on.

Open University

In the UK our experience with the Open University may lead to new thinking about Higher Education in general. In an age when information of any kind can be communicated to a student at any place, what is the optimum balance between local study, and study away from home within the environment of a learned institution? Do satellites have a role to play in these new forms of Higher Education?

One of the dangers we have to guard against in educational planning, which the report emphasises again and again is that of complacency of thinking that there is plenty of time before problems become pressing. Are there any pressures building up now? The present limit of Open University broadcasting is 30 hr. per week. As the University grows into its third and fourth years, faculty demands for broadcast time will also grow. There are many less obvious problems: at say 5.30 – 6.00 pm. only (say) 65% of the potential audience for some particular programme will have arrived home. By 6.30 this may have risen to 85%. Later than this, the evening entertainment programmes are taking over the channel.

Consider schools broadcasting: for many years they have occupied the morning and afternoons. Now, partly through the de-restriction of broadcasting hours and partly through changing social habits with adult audiences available for viewing in the middle of the day, the school educational broadcasting time is becoming increasingly vulnerable. We

are now seeing them forced out of the afternoons, for reasons which are totally without educational validity. The moral of this is: do not imagine that pressure on broadcast space for education is of the future; it is here with us now and quite an urgent problem.

European Institute for Co-operation

One of the new interesting developments within Council of Europe thinking is that of a European Institute for Co-operation between universities and other institutes in the field of 'multi-media distant study systems' – our type of Open University activity, i.e., systems and materials which can be used in situations in which the permanent presence of the student is not essential.

Suppose for arguments sake, that such an Institute was set up in some city in Europe. It would require easy and rapid access to all European universities, to specialist libraries and information centres that already exist, and which could not sensibly be duplicated within the new institute. Is this complex network of communication such that it can only be solved by a satellite service?

Finally I mention a rough figure which has been quoted to me in relation to providing a satellite service covering the UK: such a satellite could now be launched and made operable for around £30m. If this is truly representative of cost it must influence one's views considerably on the implications of satellites for educational purposes since it appears to be comparable with costs for terrestrial systems and may even show advantages.

SPACE-TECHNOLOGICAL ASPECTS OF EDUCATIONAL TV*

By Dr. N. Simmons

Introduction

This paper does not start from the position that space techniques are necessarily the answer to all, or to any, educational problems. Its aims are, simply, to examine what will be the situation if educationalists demonstrate a need for aid going beyond the limitations of a video player with canned programmes, so that live TV must be transmitted, in which case space methods of transmission must undoubtedly be considered along with terrestrial alternatives. It is important to expose the potentialities of space technology for this purpose, the particular features of the satellite solution, and any limitations that might react upon the nature of the educational service it could provide.

For the purposes of this mutually informative dialogue between educationalists and space technologists, no attempt will be made to present space information in a fully comprehensive and quantitative way: rather, the hope is to summarise the important factors in an assimilable form for those whose familiarity with advanced technology may stand at the same low level as the author's understanding of modern pedagogic practice.

'Educational TV' is a term with a variety of interpretations. They fall, however, into two categories, between which we shall distinguish for reasons of space technology:

A *Domestic Service*, available to the household set which, subject to the provision of an adequate quality of picture and sound, must, together with a simple and cheap antenna system, be a minimum – cost installation.

B *Limited-access service*, available to special sets and installations, i.e., above the norm in cost and possibly in complexity.

In terms of 'educational' programmes, in developed countries where system A exists, e.g., in Western Europe, the medium is exploited for the distribution of cultural material and it could, in principle, be available also for instructional programmes on the lines of the British Open University. In developing countries, system B can provide all sorts of services to the population, including educational programmes, through the village or 'community' TV concept. It could also be used in developed countries, alongside A to provide, for example, a specialised service to schools and other institutions of formal instruction, though this has, so far, been done only experimentally.

For space solutions, there are material differences in the technical characteristics of A and B arising from the fact that, in a limited-access service, because a larger audience is assembled, unit cost would be set at an optimum rather than a minimum figure. Moreover, different frequency bands are now assigned for the two cases.

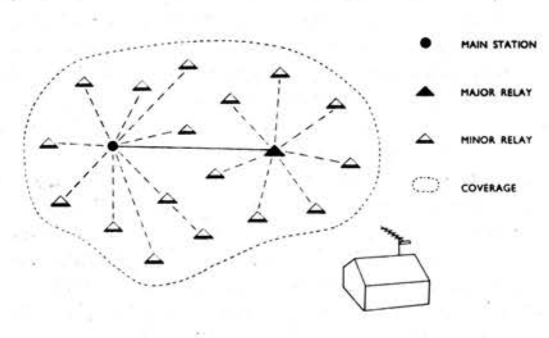
First, however, it is necessary to examine briefly the terrestrial system of distribution, which is basically of type A to ascertain its current and future possibilities for providing educational programmes of both A and B varieties and to take note of its long-term limitations, which evoke the need to consider the space alternatives.

The Terrestrial System of TV Distribution

The terrestrial system can be briefly described by reference to existing facilities in the U.K.

Since the reach of a ground transmitter is limited both by its power and by topography, it is found economic to achieve coverage by a hierarchy of main (high-power) stations, supplemented by major relay stations and a great number of minor relay (fill-in stations), all linked by a network of co-axial cables and microwave links (Fig. 1). The system is closely tailored to population distribution and ground relief. Three programmes are at present transmitted,

* *Paper presented at the B.I.S. meeting on 'Space Communications Systems for Educational Purposes' Southampton, 21 September 1972.*



TERRESTRIAL SYSTEM OF TV BROADCAST

each requiring its own facilities, but these are largely co-located to secure obvious economies. The whole system has been built up in an evolutionary way, first to cover the populous areas, then the less populous ones, by in-filling. This process becomes increasingly difficult and expensive as the limit is approached (mountainous regions tend to be sparsely inhabited) but coverage in the VHF band is now over 99% of the population. In the UHF band, the difficulties are greater because of the smaller range of each transmitter but the figure should eventually reach 95%.

The UK has an allocation of wavelengths for terrestrial TV broadcast in both the VHF (below 300MHz), where a total bandwidth of 69MHz is earmarked, and the UHF (above 300MHz) where a total bandwidth of 352MHz was made available: both are exploited but the UHF not fully as yet. The present utilisation of these spectrum allocations in the UK is complicated by a strictly national and temporary phenomenon – the changeover from the 405 to the 625-line standard, with overlapping services. As this is irrelevant to the present discussion the system will be considered as it could be at some future date when the UK is on a single line-standard, and when the available spectrum is optimally and fully utilised.

Now the transmission of a colour TV programme by a single transmitter to the existing type of domestic receiver (i.e., AM vision, FM sound) requires 8MHz of radio frequency bandwidth, but the process of covering an extended area demands, on average, a set of eleven such channels, in order to avoid overlapping interference. Thus the total spectrum required nationally per programme is about 88MHz. The UHF provision will accomodate 4 colour TV programmes: the VHF provision, inadequate for this purpose, will present a problem as to its best development. At all events, the potential capacity of the system is limited, to a level not far beyond its present utilisation. A similar situation exists in Western Europe generally.

Although the spectrum allocation is under-utilised in the UK (and elsewhere) at the present time, the provision of facilities is extending under the limitations of available finance in accordance with a demand that is quite clearly growing. Depending upon economic factors, the available spectrum is likely to be exhausted by the end of this decade, both in the UK and in Western Europe generally. Nevertheless, the pressure for more programmes, whether reacreational, cultural or instructional, is not likely to cease at that point and the problem has now to be considered, how will the demand be met after that date? In fact, in the UK, six services of national coverage has already been set as an eventual objective [1]. Presumably, the new TV Advisory Committee now in session will address itself to this problem among others. Here, only a personal and non-official view can be offered.

How are educational requirements likely to fare in this situation of over-crowding? The cultural type of service will continue to be part of the general competition for programme time, disadvantaged perhaps by the circumstance of being required by a minority public. Instructional programmes will be a harder case still, especially if intended for limited access. It is interesting to speculate how much total broadcasting time and how many parallel channels such programmes might, ideally, require. However, it seems most unlikely on present indications that instructional services could obtain a dedicated TV channel against the competing demands of other, and more lucrative services. No doubt, to some extent, time-sharing is possible, since instruction and recreation tend to have different peak-viewing times. In general, however, educational services are likely to become the junior partner in an ever more intensifying competition for broadcast time, while the total facility remains so limited.

The inevitable outcome, both for educational and for other TV services, will be to enforce the use of higher frequencies for terrestrial broadcasting. (The alternative of distributing programmes by wide-band cable to households, in the manner of a telephone service, is probably too exorbitant to contemplate). Such moves can take place, of course, under the regulating powers of the International Telecommunication Union (ITU). Nevertheless, it should be emphasised that to move thus up the spectrum is normally a matter of increasing difficulty and expense from the technical point of view: the smaller wavelengths correspond to an increasingly miniaturised electronics technology, and we have already seen that the range of a UHF ground station is much reduced as compared with VHF. The resulting conflicts of interest are resolved, under ITU auspices, at occasional sessions of the World Administrative Radio Conference (WARC). The usual outcome is that existing users, authorised by previous sessions, are not disturbed but new ones must accommodate themselves to newly-assigned frequencies higher up the spectrum, despite the extra cost and even where one is taken in advance of current technology. Thus the terrestrial distribution system in Europe is likely to be forced, for future extensions, to SHF, i.e., frequencies above 1GHz (1000MHz).

The problems of coverage at SHF band will be more acute still than those already mentioned and so also will those of the domestic installation. No figures are available to the author of what the capital cost of the existing distribution system in the UK will have amounted to at the point when saturation is reached but it must be upwards of £100M. For a system in the SHF band, the costs must be at least several times greater and thus of considerable economic importance whether it is a matter of commercial, recreational or educational broadcasting.

Because of this not very favourable prognosis, it is necessary in Europe to consider satellites for doing whole or part of the task, i.e., either transmitting programmes directly to domestic receivers or to the small local stations

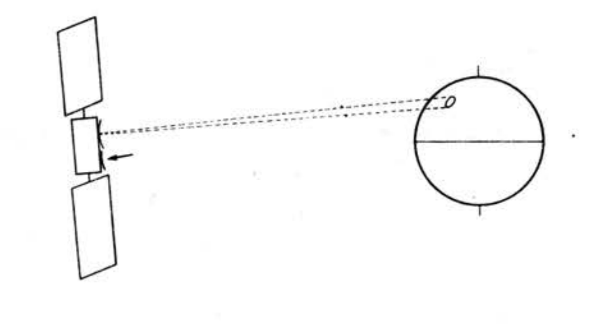
which can then distribute to households, primarily by wired connexions to conserve radio spectrum. In developing countries, the absence of a terrestrial system often points the same way and the space alternative is being actively considered. Equally, in large but sparsely populated territories such as the Western USA, Canada and Australia, the space possibility has materialised early enough in the history of their communications development to receive favourable attention before the terrestrial method has been fully exploited.

The Space System of TV Distribution

Space methods have been in use for some years on long-distance transmission of TV programmes, e.g., from USA to UK, where they are fed into the terrestrial network. It is not in this sense but rather as a primary means of *distribution* that it is necessary to consider what satellite systems have to offer.

The space possibility rests upon the concept of a geostationary satellite (Fig.2). If a body is set at an altitude of 19323nm. over the Equator with the appropriate orbital velocity, it will, according to Kepler's Laws, circle the Earth with a period of precisely 24 hr. and so will be effectively stationary with respect to the Earth. If it is also stabilised in attitude against disturbance (e.g., solar radiation pressure, micro-meteorite impacts) and in position (due to non-sphericity of the Earth), it will provide a fixed and evelated platform usable as a radio relay station. That is to say, radiation can be received from a suitably directed ground transmitter and, with the aid of an on-board power source, responder and antennae, amplified and re-transmitted in any required direction or to a specified area on the part of the Earth that the satellite can see (its whole possible angle of view being about 17°). Non-geostationary satellites could also be used in this way but the fixed geometry of the geostationary satellite presents the obvious advantage that ground receiving antennae look in a constant direction and may even be fixed.

That the geostationary satellite concept is generally feasible is indicated by the existing global system of long-haul point-to-point communications, known as Intelsat IV. (The non-geostationary counterpart is Molniya). The satellites of this system are of nearly 500Kg mass and are put into position by the Atlas Centaur rocket. In launcher terms, this is a medium-scale operation nowadays. If it were necessary, larger satellites could be put into geostationary orbit – Saturn V could emplace a spacecraft of 30 tonnes



SPACE SYSTEM OF TV BROADCAST

but, of course, at correspondingly higher expense. The Intelsat IV satellites however probably represent the largest size necessary for point-to-point communications in the foreseeable future. They have a large and diverse range of capabilities (e.g., simultaneous point-to-point relay of 12 colour TV programmes) and a design lifetime of 7 years (set by the fuel used for manoeuvre and other factors).

The fact of Intelsat IV shows that operational geostationary satellites are feasible in the aerospace sense, costable, and economic as against terrestrial methods (in the case of point-to-point relay). Broadcasting is a different case and it is necessary now to examine this from the viewpoint of feasibility in the communications sense and the system economics.

There are some important differences between broadcasting and point-to-point relay. In the first case, the down-beam from the satellite must be designed for area coverage and operate to modest ground antennae: in the second, the tendency is towards pencil beams received at stations such as Goonhilly with antennae of 25-30m diameter and correspondingly sophisticated equipment. On the other hand, there are compensating simplifications: thus, the transmission delay of about 0.4 sec. on the up and down path, which can be an embarrassment in telephone conversations, is of no consequence in a one-way transmission.

The requirement to receive with small-scale equipment not requiring the constant attention of telecommunications engineers in the broadcast case means, in the end, that the density of radiation at the ground must be high and that the satellite must transmit at high power. We shall find that sufficient power is available on current and prospectively available technology and that the other associated problems are also soluble in principle. But the power issue does have the consequence that services which can tolerate an above-standard antennae and installation (limited-access, Type B) are likely to be realised sooner than a domestic service (Type A).

It should also be noted that a geostationary satellite designed to broadcast over a given area, be it national or regional, becomes in effect a dedicated facility – unlike the non-geostationary satellite.

Some Technical Aspects of Space Broadcasting

In the above brief qualitative account, we have glossed over technical details, some of considerable importance. It may be of interest now to review some of these aspects, still rather cursorily. Types A and B will be dealt with together recognising that, from a technical viewpoint, A is an extreme form of B. The aspects especially worthy of attention are:

(1) satellite power requirements;
(2) operating frequencies and spectrum economy;
(3) co-ordination, i.e., avoidance of interference with other systems.

There is interplay between these various factors. Thus, the ordinary TV receiver operates on a system whereby the carrier wave is amplitude – modulated (more precisely, AM-VSB) for video (sometimes FM for sound), which would require enormous power in the satellite: this can be greatly reduced by the use of frequency modulation for video, the ground receiver then requiring a FM to AM converter, but

at the expense of a greater usage of frequencies. The RF bandwidth of 8MHz may need to be increased 3 to 5 times, according to circumstances (though it still compares well with the 88MHz required by a terrestrially – distributed programme). This in turn makes it more difficult to satisfy numerous demands within a limited frequency provision, in particular, to co-ordinate one country's requirements with another's. On the other hand, taking advantage of the directional properties of propagation at higher frequencies, it is possible to instal broadcasting satellites fairly densely on the equatorial geostationary 'girdle'. And so on. The problem is complicated but it has been clear for some time that solutions can be found, that systems can be designed within the limitations and reasonable in cost. An analysis of the European case appears in Ref [2].

Indeed, the promise of broadcast satellite systems has generated great interest in the United Nations, especially on the part of developing countries such as India and Brazil and those such as Canada with a large area problem. In 1969 the UN set up a Working Group on Direct Broadcast Satellites, which reported on feasibility, time-scales for implementation and economic and legal aspects [3]. Following this initiative, a thorough basis of technical and costing work was carried out in the CCIR (International Radio Consultative Committee) of the ITU, which confirmed the feasibility of such systems and assigned authoritative costs to both space and earth segments [4]. In particular, the possibility was established of satellites up to 1350 Kg and associated ground systems in the ranges of 800MHz, 2.5GHz and 12GHz. This activity led up to the WARC meeting of mid-1971, where frequency allocations and other regulatory provisions were agreed internationally for this new application of space technology, among others [5]. Previously, the establishment of a broadcasting satellite would, on a strict interpretation of ITU regulations, have been illegal.

Five frequency bands were allocated by the WARC for broadcasting satellite down-links, as follows:

620-790MHz (UHF) This is restricted to TV in the FM mode but applies a severe limitation on the power flux density at ground level to protect existing terrestrial broadcast systems.

2.50-2.69GHz This is a provision for national and regional systems of community reception (i.e., Type B only), shared with fixed and mobile services. Limits are imposed on power flux density, that in practice enforce the FM mode.

11.7-12.5GHz In Western Europe, this provision of 800MHz is to be shared by broadcasting satellites on an equal primary basis with terrestrial broadcasting and some other services: it is otherwise unrestricted. A frequency planning conference is necessary but the allocation should be enough to permit each of the Western European countries to deploy 4 satellite broadcast programmes. In other areas of the world, there is a corresponding but less extensive provision.

41-43GHz and 84-86GHz These will be exclusive bands for satellite broadcasting in the future but there is no early prospect of the technology being equal to their operational utilisation: preparatory study and development will however be possible.

The effect of these provisions varies in different parts of the world because of the different impact of competing services already installed. In Western Europe, because of the established terrestrial networks, it is very unlikely that national frequency administrations will allow the use of the UHF band for satellite broadcasting and the 2.50-2.69GHz band, although possible, is of such modest width as to be of only limited interest. The preferred band will be the much greater provision at around 12GHz. On the other hand, in developing and in large sparsely-populated countries, the 2.50-2.69GHz band is likely to become the main one, at least in the first instance, because it is at about these frequencies that total system costs are least. Here the service will be of Type B,extensible where finance permits to Type A by making each reception point a local relay station.

Both in Europe and elsewhere, FM transmission of video would be preferred, even where it is not enforced, because the AM alternative would require a satellite of many times the power and mass and, in the 12GHz band, the individual receiver must be modified in any case by the introduction of a frequency-changer. Thus, where it is a question of adding to an existing service, FM to AM conversion must be installed at the reception point. Where it is a matter of a new service of Type B a new FM-only type of receiver might be used.

The opening by the ITU frequency allocations of a licit, regulated pathway to the establishment of broadcasting satellite systems has been followed by further studies both by CCIR and by commercially interested parties. Various specific project proposals have been elaborated [6, 7]. Because of the variation in geographical and other circumstances, caution is necessary in extrapolating these studies from one location to another. The general situation is as in Table 1.

Table 1.

	Type A	Type B
Unit Cost	Minimum	Optimum
Antenna	Simple, Cheap	More Elaborate
Satellite Power	High	Moderate
Frequency – Europe	12GHz	12GHz (& 2.5GHz)
– Elsewhere	2.5GHz, 12GHz	2.5GHz, 12GHz
Probable Utilisation		
W.Europe	Recreational & Cultural TV	Instructional TV
Developing Countries	Very Limited	Community TV
		Instructional TV
Large, sparsely – populated countries	Recreational & Cultural TV by Type B with re-distribution	

The issue of spectrum economy is closely bound up with the picture quality to be provided. The parameter expressing quality of video service is the luminance signal-to-(rms weighted) noise ratio (SNR), which for 'CCIR-quality' relay is laid down as 56dB. Following the WARC conference, CCIR recommended that, for 'community' TV,a relaxed standard of 45dB could be used. The effect of different SNR standards upon the radio bandwidth occupancy has been analysed [8]. The results are virtually the same for UHF, 2.5GHz and 12GHz, the averaged values being as follows:

SNR	35	45	55db
Bandwidth	15	23	40MHz

Thus, allowing for audio and protection bands, a 45dB service finds 5 channels in UHF, 6 in the 2.5GHz band and 27 channels in the 12GHz band. A 55dB service finds 3, 4 and 16 channels respectively. It should be noted that the CCIR relaxed standard apparently relates to type B service in developing or sparsely-populated countries. For a Type B service applied to instructional use in Europe, it would be highly desirable to maintain the normal standard to which the viewer is accustomed on his general TV service, which may however fall well short of 'CCIR quality'. A SNR of 45dB, which corresponds with an 'excellent' rating of picture, can fairly be taken as a basis and it will be seen that the ITU allocations make a quite favourable provision to facilitate such services.

The remaining aspect to be considered is that of co-ordination. Radiation received at the ground from a satellite does not show the rapid drop away from the centre that is characteristic of terrestrial transmissions. Between the centre of the designed coverage zone and the periphery, the field strength will fall only to half. This very feature poses the problem of overlap into neighbouring countries. While deliberate intrusion is offensive politically, even unavoidable overspill will be resisted in countries where the media are controlled.

Technically, the problem is to have enough frequency bands at disposal to ensure that contiguous areas do not need to use the same channel and reducing co-channel interference to a factor of about 30dB. The process can be assisted by diversifying the satellites and using the antenna discrimination that is available at high frequencies. The treatment of this problem is mathematically complex and the interested reader is referred to an excellent analysis in Ref. 9, which shows that, for the case of Europe, assuming an available 400MHz bandwidth in the region of 12Ghz and 3m reception antennae (i.e., Type B), 4 programmes would be provided to each country. For domestic service and 1m antennae (i.e., Type A), the co-ordination problem is still soluble but requires a 16-fold increase in satellite power.

It can thus be seen that solutions are at hand to the various communications problems mentioned above. It should also be mentioned that the component technology for the 12GHz band is now well advanced. There is therefore, every practical possibility of realising satellite broadcasting systems in the near future, starting with Type B, provided there is a user demand and subject to satisfactory economics.

To complete this section, it is of interest to mention briefly two practical developments that are now in train:

ATS-F&G (Applications Technology Satellites)

These are two virtually identical satellites which NASA plans to launch in 1973 and 1975 for a large number of technological missions, including the testing of satellite broadcasting, both technically and operationally. The design is a geostationary spacecraft of 1260Kg at launch, 3-axis stabilised and carrying a 9m diameter parabolic mesh antenna capable of operating at frequencies up to 10GHz. For the first year after launch, ATS-F will be employed on tests in the USA, including Alaska, at 2.5GHz, related to primary school education, public broadcasting and medical consultation: the associated ground system will consist of about 500 low cost ground stations ($500 to 1000 each). Thereafter, ATS-F will be re-positioned at 35°E longtitude to operate in India the well-known SITE trial (Sateliite Instructional TV Experiment): about 2000 Indian villages will be provided with low-cost receiver stations (3m antennae) and the experiment will be conducted in the UHF band. The mission of ATS-G is not yet finalised but educational TV will be possible at increased power.

CTS (Communications Technology Satellite)

This is a joint venture of the USA and Canada, for launch in 1975 to test the use of the 12GHz band for satellite broadcasting. CTS is a 3-axis geostationary spacecraft of a size capable of being launched by the Thor/Delta rocket system, i.e., up to 800Kg initial mass. There will be equal usage by the two participating States in experimental services of community TV and sound radio, 2-way voice communications and data links. The project will also study propagation problems in this band due to weather.

In Europe, regretfully, there are as yet no comparable projects under way. On the other hand, useful studies have been carried out relative to European conditions [2, 10]. In particular, these go in some detail into the cost aspect, which must be the next item for attention.

Satellite System Costs

Evidently, various space systems are possible, depending on the type, volume and quality of service to be provided, the area to be covered (national, regional, continental) and the frequency band utilised. To give an indication of costs, one example will be taken – the case of a European country, both Types A and B service, and the 12GHz band. The following indicative figures are based upon the careful, but tentative, analysis of Ref. 10.

Consider a satellite of 700Kg orbital mass, stabilised to 0.1 degree accuracy in attitude and irradiating an area equivalent to a 1.4 degree cone (half-power boundary). On the ground (at 50°N), this corresponds to upwards of 300,000 $(nm)^2$ – ample for any one Western European country or language zone (compare UK 72,000 $(nm)^2$, France 160,000 $(nm)^2$). Such a satellite could dispose 800 watts of radiated power, enough for a single programme of Type A service or 3 programmes of Type B. The capital cost of the space segment, consisting of 3 satellites (one spare in orbit and one spare on the ground) plus their launchings and support expenses would be about $100m. Five years later, it would require renewal at a further cost of $100m. These figures exclude satellite development charges. Assuming a fair basis of pre-existing technology derived from other advanced communications satellite projects, this development might cost of the order of $100m. but, if a common type were developed for participating countries and shared financially, this would represent only a marginal addition to the system costs.

It is necessary to consider also the unit cost of receiver equipment under the two systems:

Type A

A satellite of the above kind could provide a single programme of direct service to households at the level of SNR = 49dB. The normal type of receiver would require the addition of a 1m diameter fixed dish antenna (gain 39dB), frequency-changer and FM to AM converter. In million-off production, the unit cost, including all associated expenses,

is reckoned at $230.

Type B

A satellite of the kind envisaged, working to an improved antenna system (2.5m dish, gain 46dB), could provide 3 channels of service at the level of SNR = 56dB (A single channel could be obtained from a 250Kg satellite with costs of $60m. replacing the $100m. figures). The receiver, antenna and all auxiliary costs, in a scale of production of 10,000 off, should amount to about $2500 (rather less for a single channel). Terminals for the ATS-F experiment have been produces and installed at less than $5000 unit cost.

The above estimates are tabulated in Table 2, where they are compared with the likely costs by the terrestrial method using similarly elevated frequencies. The expense of covering the terrain in this way is set, perhaps optimistically, at $720 per square Km [10] so that the capital cost for 100,000 $(nm)^2$ would be about $250m. per channel, with a lifetime of perhaps more than 10 years. The user costs, whether A or B, would be little less than those for the space case.

Table 2.	Type A 1 Programme	Type B 3 Programmes
Space		
Transmission system capital cost	$200M	$200M
Receiver unit cost	$230	$2500
Terrestrial		
Transmission system capital cost	$250M	$500M
Receiver unit cost	$200	$2500

On cost grounds alone, the space method, prima facie, compares favourably with the terrestrial method extended to higher frequencies. Additionally it is at least as economical of that other scarce resource, the radio spectrum. Of course it will still be necessary to justify the cost of a space system in absolute terms as against the benefits of any proposed service.

Conclusions

Various educational services can be conceived – for different circumstances in developing and developed countries. From a technical viewpoint, they can be put into two categories: Type A, where the programme reaches the consumer on his individual receiver and Type B, where a group is served by one equipment on which, therefore, a higher unit cost can be accepted.

It has been shown that such services can be provided by space means. The basic arrangements have been made internationally for allocating frequencies and settling the modalities of shared usage: the remaining necessary international arrangements for deciding which countries will be assigned which frequencies will be settled in due time. Moreover, the technology is available and pilot trials have already been started to test these usages in practical conditions.

It seems clear that the cost of space schemes, for which indicative estimates have been given, may well prove more favourable than for the corresponding terrestrial method, once the capacity of the existing networks has been fully taken up. Of course, this relativity must be carefully verified in any specific case.

The development of a specific satellite may take 4-5 years but educational software and training may well take longer than this.

Thus the time seems ripe to plan for the exploitation of space for educational TV (as also for recreational TV), provided always that the cost of such a service can be justified by its expected benefits. This justification ia a task for the educationalist.

REFERENCES

1. Report of the TV Advisory Committee 1967, HMSO 1968.
2. N. Simmons, 'Some possible concepts for a second phase of communication satellite developments in Europe'. 9th European Space Symposium, London, May 1969. *Spaceflight,* Oct. 1969.
3. Reports of the UN Working Group on Direct Broadcast Satellites. UN Documents A/AC. 105/51 and A/AC.105/66, 1969.
4. UNESCO comments to the UN Working Group on Direct Broadcast Satellites. UN Document A/AC.105/79, Apl. 1970.
5. D.E. Baptiste, 'Frequencies for space communication', *Wireless World,* Sept. 1971.
6. R.G. Zeitoun and C.A. Siocos, 'Broadcasting from satellites – UHF TV channel utilisation', *Journal of the SMPTE,* Mar. 1972.
7. D.R. Wells, 'A combined educational and TV network satellite distribution system', *Journal of the SMPTE,* Mar. 1972.
8. R.P. Haviland, 'Possible technical standards for educational and community TV by satellite', *Journal of the SMPTE,* Mar. 1972.
9. A.K. Jefferis, D.G. Pope and P.C. Gilbert, 'Satellite TV distribution: service from geostationary satellites to community antennas in multiple-coverage areas', *Proc. IEE,* **116**, 9 Sept. 1969.
10. J.P. Contzen and S.H. Hanell, 'Some technical and economic aspects of a future TV broadcast satellite system in Europe', 11th European Space Symposium, Berlin, May 1971.

INTERNATIONAL CO-OPERATION FOR SPACE BROADCASTING*

By E. Lloyd Sommerlad†

Introduction

The development of communication technology over the past century has been a most potent force in creating the internationalism which is an indispensable feature of modern life. No country, today, can isolate itself from its neighbours. Radio waves recognise no frontiers; hostile messages cannot be shot down or turned back at borders.

Long ago, the first primitive techniques of transmitting signals by wire raised problems which forced neighbouring states to consult and co-operate and indeed to lay the foundation for international regulatory action. The history of the International Telecommunication Union is the story of international co-operative arrangements following closely upon technological developments. In the mid 19th century, when national frontiers were even more sacrosanct than they are today, the transmission of a telegraph message from one country to another posed serious problems. The practise, for the sake of respecting this sacred line, was for the international telegram to be first decoded at the telegraph station on one side of the border, then handed to a courier, who with passport crossed the frontier, and took the message to the nearest telegraph station in the next country for encoding and onward transmission. To overcome these impossible obstacles, an international conference was convened in Paris in 1865 to establish an institutional framework for co-operative action – the International Telegraph Union. Gradually the Union expanded its functions, and merged with the International Radio Telegraph Union in 1932, changing its name to that of the present United Nations specialised agency – The International Telecommunication Union.

Now, in the late 20th century, space age technology is further challenging the traditional conceptions of national independence and compelling a recognition of the interdependence of nations in the modern world.

In 1945, there were no transistors, no computers, no trans-Atlantic telephone cables, and communication satellites had barely been thought of. Even TV had not been commercially exploited. Over the last quarter century these new inventions have come into common use and even more sophisticated communications hardware is in course of development. The key question is whether these technological achievements will be applied to help solve the urgent global problems that threaten world peace and progress. This will require international agreement on technical, legal, political and administrative levels, as well as co-operative action in space applications.

Promising progress has already been made. The United Nations Outer Space Treaty of 1967, providing, inter alia that outer space shall be free for use by all states without discrimination of any kind on a basis of equality, has been signed by most nations, including the two space powers.

An application of this principle is to be found in some of the decisions of the World Administrative Radio Conference for Space Telecommunications, convened by the ITU in 1971. The Conference decided, for example, that as all countries had equal rights in the use of both radio frequencies and the geostationary satellite orbit, the registration with the ITU of frequency assignments for radio communication services and their use should not provide any permanent priority for any individual country or group of countries, and should not create an obstacle to the establishment of space systems by other countries. This is of particular importance to developing countries which may as yet have no clear view of their future needs for space broadcasting. For them, the door has been left open, for some years at least, and their fears should be allayed that the 'first come, first served' principle may exclude them from future space benefits.

Cultural and Social Impact

Unesco has also been studying the cultural and social impact of satellite broadcasting and has just completed the preparation of a Draft Declaration of Guiding Principles on the use of Satellite Broadcasting for the Free Flow of Information, the Spread of Education and Greater Cultural Exchange. This will be submitted to the General Conference on Unesco for adoption at its next session in Oct.1972. This responds to the concern expressed by many developing countries, that unless international agreement were reached they might be exposed to satellite broadcasts of foreign origin that were objectionable on either political or cultural grounds. The proposed Unesco Declaration would not constitute a binding legal instrument but is intended as a statement of principle, backed by the international community, for guidance in the development and use of space broadcasting. Among the principles enunciated is the right of each country to decide on the content of the educational programmes broadcast to its people and to participate in their production; the right of all countries and peoples to preserve their cultures as part of the common heritage of mankind; the need to reach prior agreement concerning direct satellite broadcasting to the population of countries other than the country of origin of the transmission.

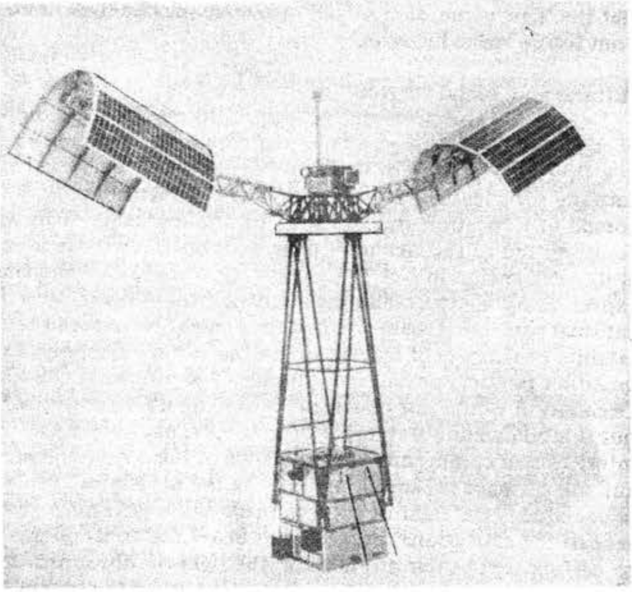
Concurrently with the establishment of an international regulatory framework for outer space activities, there is need for co-operation in the practical applications of space technology. Here again, there has been an encouraging start. In the field of meteorology for example, two operational weather satellite systems, the TIROS system of the US and the METEOR system of the USSR have been linked together as part of a world-wide meteorological network called the World Weather Watch under the auspices of the World Meteorological Organisation.

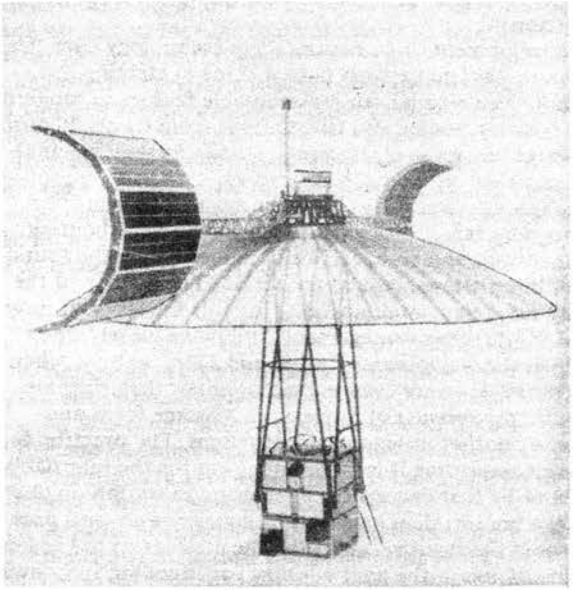
In the field of space communication, INTELSAT now has more than 70 members who co-operate in the ownership and operation of the international telecommunication system which, among its many services, has brought live coverage of overseas events – and even lunar events – to our TV screens. The Soviet satellite system is also being expanded into an international system called INTERSPUTNIK, whose membership is open to all states.

Another significant contribution to co-operation in this field, has been made by non-govermentai organisations, at the professional level. There has been steady development in recent years of co-operative arrangements for programme exchanges both within and between the various regional broadcasting unions. Initially applying to relays over terrestrial broadcasting systems, exchanges are now beginning to take place by means of satellites. Common interest in programme material has led to the emergence of joint ventures such as Eurovision and Intervision under the auspices of Western European and Eastern European broadcasting unions respectively, and to exchanges between them. Similar patterns of co-operation are developing in Africa, Asia and the Arab States.

* *Paper presented at the Symposium of the British Interplanetary Society on 'Space Communication for Educational Purposes' Southampton, 21 Sep. 1972.*

† *Office of Free Flow of Information and International Exchange, UNESCO, Paris.*





Engineering model of ATS F and G shows the spacecraft with the 30 ft. diameter antenna dish in the stowed and deployed positions. The solar array consists of 2 semi-cylindrical panels supported by deployable booms. The Earth Viewing Module, approximately 4.5 ft. square and 5.5 ft. high, is suspended beneath the open truss framework. This has 3 separate compartments. At the top is the communications module, in the middle the service module that houses attitude control and telemetry, and at the bottom the experiment module which also includes power sub-systems. Spacecraft is approximately 25 ft. tall; span over deployed solar arrays is 52 ft.

Fairchild Industries

But at the present time, the operational space communication systems only permit point-to-point TV relays, for subsequent retransmission by conventional terrestial stations, which mostly serve urban areas. The communication revolution has not yet penetrated to the rural peoples of developing countries. The next generation of communication satellites, however, capable of transmitting radio and TV programmes directly to community receivers in the remotest areas, hold great promise of extending and improving education through the expanded application of TV.

Unesco sees space communication as one of the new technologies which are opening up the possibilities of re-forming the whole process of education, of removing the barriers which have stood in the way of equality of access to education and for so long have retarded the social and economic progress of two thirds of the world's population. It probably constitutes the best practical solution to one of the most perplexing and crucial problems of the countries in development – the ever widening gap between the educational levels and opportunities of the urban and rural populations.

The 'Educational Crisis'

The problems of the Third world have been aptly described in the following terms, in a report in 1971 on Space Communications, by the UN Association of the US:

'Countries of the less-advantaged world community confront severe educational crises. Illiteracy is widespread. There are some 800 million illiterates today – 100 million more than two decades ago. Badly needed medical, technical, and agricultural skills are scarce and often must be imported for want of sufficient trained manpower at home. In sum, the demands for expanded training opportunities – at all levels – far exceed the capabilities of traditional educational systems. Beyond these quantitative demands are the qualitative requirements for better teachers and new curricula that offer more scientific and technical instruction. The educational problem directly affects the general level of economic productivity and social progress and requires priority attention and resources in finding adequate solutions.

Maintaining even a moderate rate of economic growth, the United Nations has noted, entails 'a widespread process of technological assimilation, extensive changes in the structure of employment, a considerable elevation of the qualifications demanded for employment in different economic sectors and a sizable increase in productivity per person employed'. If the educational system is not geared to produce the needed manpower, development is bound to be retarded.

The very enormity of the educational challenge has stimulated interest in trying new and perhaps even radical methods in the hopes that they might achieve better results. Modern media, in particular, are now regarded by many low-income countries as basic tools in any educational offensive'.

Space technology has opened up for all countries the exciting possibilities of universal TV, of news and cultural exchange and education for all, but for most countries, the possibility is still tantalizingly out of reach.

Preliminary studies made by Unesco make it evident that a space system can only be economic if it addresses itself to a large audience. Comparatively few countries, individually, have the means and the population that would justify the installation of a domestic satellite system for education. A regional approach, however, may offer a solution, with a sharing between co-operating countries of both the hardware and the operational costs, including at least some production of common programmes.

Unesco has already responded to requests to make preliminary regional studies of the possibilities of space communication to aid education and development. Surveys have been

undertaken, in co-operation with the International Telecommunication Union, in Latin America, the Arab States and Africa South of the Sahara.

Although illiteracy in Spanish-speaking South America has decreased compared to the total population during the last two decades, it continues to rise in absolute terms. The educational systems of the region suffer from a high pupil wastage rate and a shortage of well qualified teachers. The quality of education at all levels is frequently inadequate, which constitutes an obstacle to fast economic, social and cultural development. The situation is particularly bad in the rural areas, where 40% of the population resides.

Having concluded that conventional measures would not remedy the situation quickly, a number of Governments in the region requested a preparatory study on the possible use of a TV broadcasting satellite system as an aid to educational and cultural development. This study was carried out in August-September 1969 by a joint UNESCO/ITU mission. The mission took into account the conclusion reached by the United Nations Working Group on Direct Broadcast Satellites that technology currently under development should make practicable in the mid-1970's direct TV broadcasting into community receivers, i.e., into specially modified TV receivers provided for groups of viewers in schools, community halls, etc. On this basis, the mission recommended the carrying out of a feasibility study, which on the request of some South American countries, has been funded by the United Nations Development Programme.

UNESCO Study

The study now being carried out by Unesco will provide the necessary basis on which the Governments will be able to take decisions on the financing, ownership, organisation and operation of a system of education incorporating modern communication technology. This system will make extensive use of new contents and teaching techniques to reach the largest possible school age and adult audience with appropraite educational, cultural and information programmes. Thus the principal objective of the study is to define and evaluate the characteristics of a regional system which can provide to the maximum number of people, at minimum cost, continuing education of high quality and best suited to their needs.

The study will include an analysis of the benefits of various communication systems using advanced technology including the use of broadcasting stations, microwave networks, cable distribution, video cassettes, films and satellites jointly or separately.

Initial estimates suggest that the capital cost of the system will be in the order of $300 million and annual operating costs in the order of $125 million. An investment and annual operating budget of this magnitude, except in a very few cases, obviously requires the pooling of resources of a number of countries.

Similar findings have resulted from preliminary satellite surveys made by Unesco in the Arab States and Africa.

The experts who recently completed a mission on the potentialities of space communication for educational purposes in Africa came to some siginificant conclusions on the economics of satellite systems.

Space technology has now advanced to a point where reasonable estimates can be made of the costs of the various components of a satellite broadcasting system – the satellite including launching, the transmitting and control station, the community reception installations, including TV sets, adapters and antennas, power sources, maintenance services, programme production, utilization and instructional materials, system management and administration.

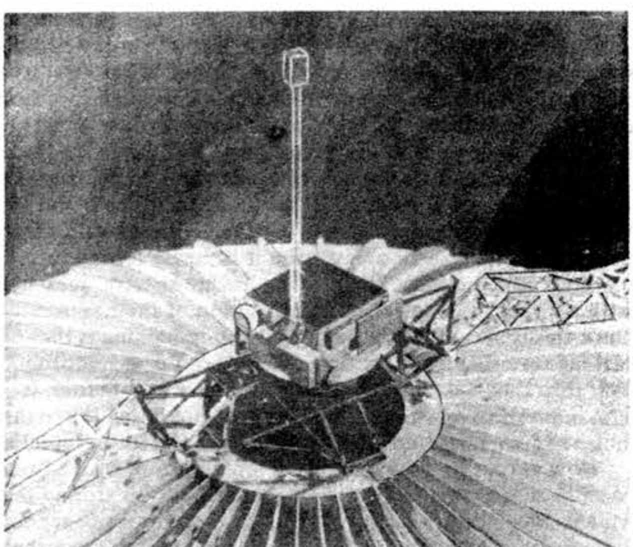
Economics

On the hardware side, the master transmitting station and the space segment are major costs which require a large service area to justify the initial investment. But as the size of the population to be covered rises, the cost of reception installations at approximately $1000 each and their maintenance soon overtakes the cost of the transmission part of the system and becomes the major cost factor.

On the software side, production of good TV programmes is very costly, but is almost invariable for a given system, no matter what the size of the audience. Other items such as instructional material and training of monitors vary with the number of schools or community reception points.

Consequently, a satellite broadcasting system can only be practicable if it addresses itself to a vast audience, when the economies of scale become evident. But total costs are formidable and require a high gross domestic product to support the system. On the assumption that educational budgets are 7.5% of Gross Domestic Product and that the total cost of an educational broadcasting system via satellite, should not exceed 10% of the education budget, the African expert mission estimated that a viable system would require at least 100 million population with an average Gross Domestic Product per capita of $200. Approximate as these figures may be, they indicate the inevitability of regional co-operation in most instances, if a broadcasting satellite system is to be established.

[Concluded on page 118



Another view of the ATS F/G satellite looking down on the 30 ft. diameter erectable umbrella antenna which focuses radio energy towards the Earth. Left and right are lattice booms of the deployed solar arrays.

Fairchild Industries

'FUTUROLOGY' IN MEDICAL EDUCATION*

By Dr. W. de Vogel†

'A Dutch media specialist visited a friend in his home on the outskirts of New York. He noticed that his friend was very disappointed to see his son sitting before the TV-screen, though it was beautiful weather (New York has 13 channels). He expressed his disappointment to his wife. She, however, had given up trying to get 4 year old John away from the television.
Then father saw a squirrel in the garden and said to his son . 'Look John, there's a squirrel!' To his amazement John left the television and walked to the glass door to look out. Father said enthusiastically to his wife: 'Look, I got him away from the screen!' John looked for 30 seconds at the squirrel and then tried to open the door to the garden, but he had some difficulties with the knob. The father, even more enthusiastic, exclaimed: 'Look, he even wants to go into the garden!' 'Don't think too much of it', his wife said, he's only trying to find another channel!'

Introduction

'Futurology' in modern planning is no longer merely a fashion but an absolute necessity. It may be only to make sure that the skeleton of each new university, medical school or hospital building is provided with the right holes and channels through which to run cables that might be needed at a future date for internal and external communications – but in all fields it is necessary to keep several steps ahead of contemporary practice. Particularly in medical education, we have to recognise that a revolutionary approach is needed if we are to satisfy the growing demand and cope with the increasing number of students. Present technical aids to education can no longer suffice if one relies solely on traditional methods. Many of the old and tried conservative methods still used in education are no longer suited to our time when technology is undergoing such explosive development. New generations of undergraduates are now appearing who, whether they liked it or not, have been subject, during much of the time when they have been maturing mentally, to emotional and audiovisual influences created by cinema or TV. The result is that students today are far better orientated to bi-sensory-perception than were those of previous generations.

McLuhan, that perhaps too much quoted Canadian sociologist, exposed the problem in a striking manner in his 'the medium is the message/massage'. The conflicts arising among young people today are partly the result of the dichotomy in teaching media. At home they are taught via a 21st century medium (TV, which can reproduce such immediate feats as the Apollo landings on the Moon and emotionally saturated programmes on crime, war or pollution, etc.), only to fall back at school or university upon methods which too often date from the 19th century or beginning of the 20th.

CCTV, Microwave Links and Satellites

The first requirement is to have audio-visual techniques and educational methods belonging to the second part of the 20th century. At the moment the most spectacular of these are:

> A closed-circuit TV system for teaching, demonstrating and expanding lecture-theatre space, with video-tape recording making repeat broadcasts possible at any time. For individual learning, we have teaching machines, slides, tape recorders and 8 mm cassette-film sets, and now also the use of colour video-cassette recording equipment.

These new methods, which have already been introduced in many higher educational establishments, and indeed have been supported by our central institute in Utrecht, called 'Foundation for Film and Science' (institute for communication – transportation of the scientific message through modern technical media for all universities in the Netherlands) have, however, only partly been able to supplant more conventional methods.

One might imagine that closed-circuit TV would have the effect of increasing the distance between student and teacher, yet it can be shown that precisely the opposite can be the case. If students have at their disposal a simple improvised yet complete TV studio, with, say, 3 black and white cameras, a control unit and one-inch video-tape equipment, they can make programmes themselves with the help of a couple of technicians seconded from the videocentre. These kind of activities are cementing links between students and teacher. Programmes made by the students themselves can have the advantage of being able to be discussed by small groups and at the same time, if they were approved by the teacher, they could be shown to larger groups or used in lectures. If the visualisation of a particular scientific demonstration is being recorded this can be discussed and criticised and then perhaps shown again to a larger group before being re-made or erased to give a different group of students a chance to study some other subject in like manner. Adoption of this technique introduces an element of competition into the study of various subjects on the students' curriculum. Contacts between scientific staff, teachers and students are thus improved and the interest created in each others' programmes arouse greater interest in the course of study itself and in TV as a medium. From this point of view teachers have to use their experience to learn to mould the technical media to their needs and they have to find the proper balance between educational conservatism and modern technology, even if it means having to use methods which replace their 'living lecture-theatre' presence with a rather more 'electronic' projection of their personality. Once this is accepted, the only problem remaining is that of making sure that 20th century teaching can pass smoothly over into the 21st century. This, as we have said before, is also a question of efficient planning, of providing the 'right holes and channels' now for the cables in the future buildings.

How are we to go about this? I am no prophet and do not wish to suggest that what is going to be built up around the videocentre in the near future will be valid for every school, university or higher education establishment, but nevertheless the new developments I have described are bound to help fashion 'new style' higher education. Some of today's developments already point out a clear path.

* *This paper was originally presented under the title, 'Experiments with Micro-wave Links between Universities in the Netherlands by PTT-System and the Future use of Terminals in this system; also related to Education Satellites Communication in the Future', at the BIS meeting on 'Space Communications Systems for Education Purposes', Southampton, 21 Sep. 1972.*

† *Scientific Director, Foundation for Film and Science Utrecht, The Netherlands.*

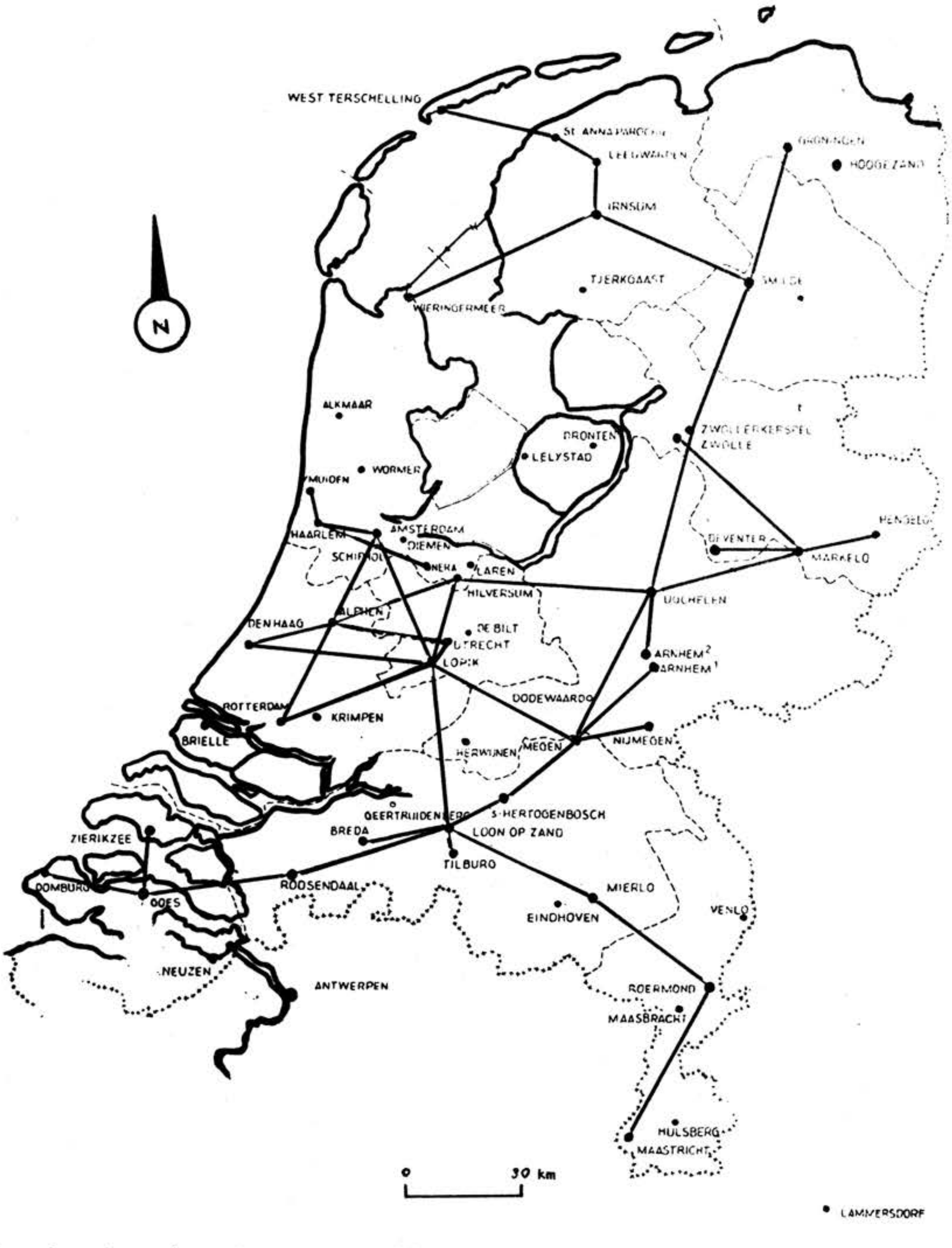


Fig. 1. Existing closed microwave link net of the PTT in the Netherlands, non-paying between midnight and 6 a.m., at which 20 terminals could be attached.

1. Sound and vision (including colour pictures) can already be relayed extremely well within a building or campus, and of course can be transmitted from one university to another by micro-wave links.
2. High-quality quadruplex (four heads) videotape-equipment or helical scan recorders allow any TV-emission from far or near to be recorded impeccably in either colour or black and white and then stored for future re-transmission or replay. A set of video-recorders would allow several broadcasts or programmes to be recorded at different times and places and then transferred into a single tape in any order desired and without any loss of quality. By centralising this equipment in a videocentre even more intensive use could be made of it, and the high cost of obtaining good quality reproduction would be more justified.
3. High-quality videotape-recordings of this type are easy to convert into either ordinary 16 mm or 8 mm cassette-films. The master tapes can also be used for re-recordings on smaller, cheaper videotape or on the future video-cassettes.
4. Recordings can be stored and classified in a computer-run library, which would allow a quick selection for re-use.
5. The software could be distributed through the air terminals of an existing closed microwave link system, run by PTT, not used between midnight and six o'clock a.m. but still

PLAN VIDEO-CENTRE IN MODERN MEDICAL SCHOOL

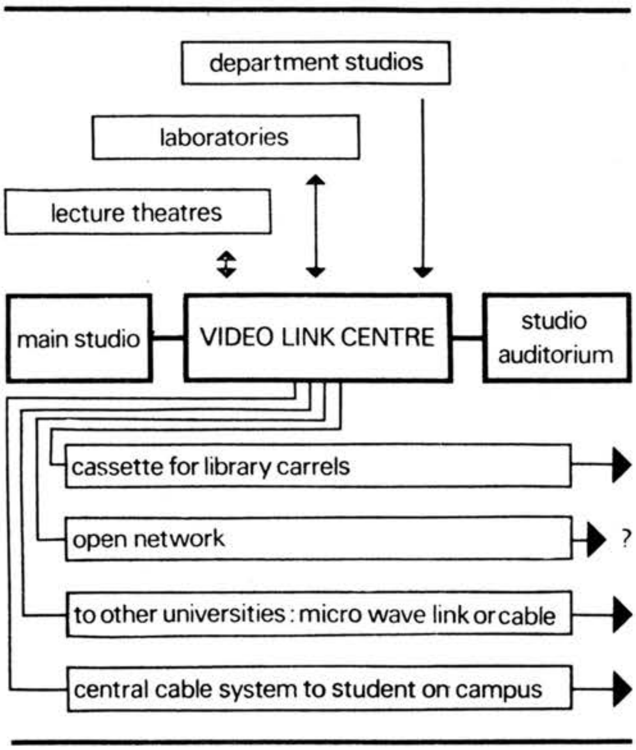


Fig. 2. Scheme of a working videocentre (the PTT microwave link must be replaced in the open network).

available. With this system software could be distributed to multiplying terminals (for example 500 cassette recorders at maximum at one terminal), mostly by cable from the terminal tower to a university, a central library, a university hospital or a PTT post-office.

If we can make at least 20 of such terminals in the Netherlands it would be possible to fill 10,000 video-cassettes, from a central point or from any educational institution attached to this microwave link. For the choice and security of the programmes this system could be introduced in every discipline with a key-system to allow the Video Post Box (VPB) to run at the time the specialised programme is put on this distribution network. The cost of obtaining such a key should be met by asking a membership fee. The key-combination could also bring in the membership number of the customer so that the customer receives a bill every month for the filling of his videocassette by the desired programme in the VPB. For example the doctors could only receive a medical key after showing their certificate of doctors degree. An association or collective of book editors, hardwaremakers, ministries, pharmaceutical and egineering firms could supply printed programmes to be sent out in advance to the keymembers for the distribution during the 5 nights of the working week. One programme should not last longer than half an hour. That means that one could send out 12 programmes a night and 60 a week. Last but not least, a European satellite could use this national PTT-system for transmitting educational material to the members of the VPB-system, who have an appropriate key for the international programmes. Our institute in Utrecht has already been contacted by the European Organisation for Research on Treatment of Cancer (EORTC) to show special cases, for evaluation, to different European centres for diagnosis of cancer patients.
I should like to stress three points:

(a) The videocentre, the nucleolus of the nucleus of the 'cell', is the most important communication centre not only for the teaching department but also the whole school or university and spreads its branches out to other education centres.

(b) If one uses satellites in modern education one should start from the experiences one has got in this field with these videocentres, running 24 hr. a day and linked to an existing national closed microwave relay system.

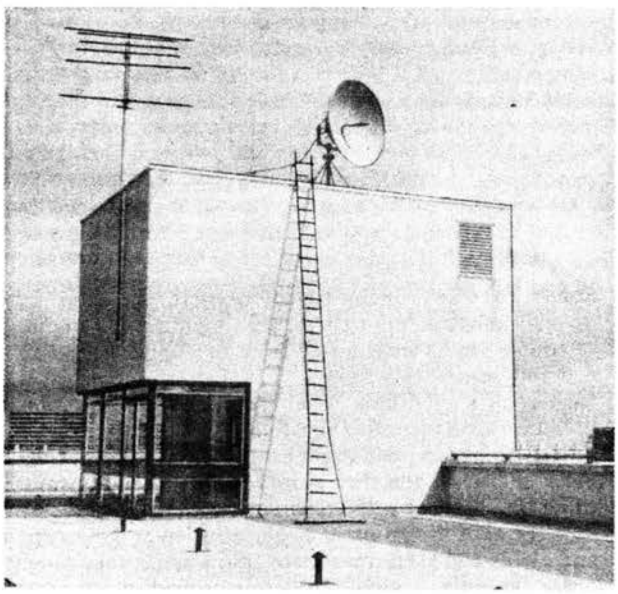
(c) Satellites would add a new dimension to information sources because the student/teacher and specialist/professor then could pick up the audio-visual information on an international basis at any time it suits him. Within 10 years the satellite could provide an opportunity to start a European Open University with a closed video-cassette system.

Conclusions

One can of course argue that all the fine doctors and scientists delivered from the medical schools of Western Europe to the benefit of mankind, between the forties and sixties, have not been educated with these modern technical devices.

Is it advisable to change the old conventional methods of preclinical and clinical teaching? For example it is recognised that bedside teaching should always be the best method for a student to become a doctor, if only to give him or her a certain feeling of confidence and some little experience

Fig. 3. Microwave link on the roof of the Foundation for Film and Science at Utrecht, the Netherlands.



before becoming a general practitioner or to specialise.

But do not forget that there is also a patient, a sick man, who can be treated nowadays without any financial discrimination in a non-teaching hospital as well as in a university medical school, overcrowded with residents and students. Has not the patient with a typical murmur in his thorax every reason to flee to a provincial hospital after having undergone an assault of cold stethoscopes of hundreds of students and interns on his chest within two days?

On the other hand, is not the medical professor, associate professor or medical teacher tempted in our hectic years of the Seventies to rush from the university to a smaller regional hospital to settle there and to help his patient, with all possible care, or do his research work in a sort of oasis? Compare this with the frustration of teaching new generations, who often prefer to discuss the democracy of the faculty and its management to finishing expensive courses as quickly as possible! A sword of Damocles hangs over the present generation which overcrowds medical schools without any restriction and has the effect of reducing the quality of medical teaching. This quality has been going down proportionally with the increasing number of students.

Do not be afraid that the solution lies only with the above mentioned communication and media-systems, but it is worthwhile giving it a thought in relation to necessary revolutionary changes in the curriculum to release the medical teacher from the extra burdens he now faces. One should also have the possibility of putting senior students and interns in small lecture rooms to view programmes on various clinical subjects, made by younger colleagues. As follow up the teacher can then be more free to start discussions with the students on these topics without having to devote all his time to the same sort of basic information. He finds himself in a more relaxed situation towards his students. Then the videocentre also offers the opportunity to spread the concentration of prospective doctors to surrounding non-teaching medical centres. By cable or by microwave links (point to point) they always have connections with clinical lessons, relayed from the medical schools or university hospitals to surrounding smaller hospitals. The link with the alma mater remains.

Last but not least the self-instruction of students by these media-methods is stimulated and by using volunteers or by doing research on themselves, e.g. by doing neurological examinations on each other, the younger students will feel more diectly involved in courses of a clinical character.

In this way the patient is relieved of too many visits and repeated examinations by students.

With these thoughts in mind I hope I have stimulated some further discussion which may help to bring about further investment in modern medical schools and university hospitals in which the media will open new prospects for less frustrations of the medical teacher, students, hospital staff and patients. Discrimination between treatment in teaching hospitals and non-teaching hospitals will then be eliminated.

VIDEO DISTRIBUTION SYSTEMS FOR EDUCATION

Mr. P. D. Whitaker of the University of Birmingham TV Service spoke for a few minutes about a report 'A Survey of Video Distribution Systems for Educational Purposes', to be published by the National Council for Educational Technology. This resulted from an investigation undertaken on behalf of NCET by a team of three people, headed by himself, and guided by a steering committee. Its purpose was to investigate, as far as possible, the distribution systems (for video signals with accompanying sound) which are currently available and those which are likely to be available in the near future or could be made so if finance was provided for development.

The survey covered the *characteristics* of a variety of *methods:*

Cable Systems – video, HF, VHF, UHF, and very wide band 'cable type' systems such as wave guides and fibre optics; *Radiative Systems* – both terrestrial and satellite – using various frequency bands, (VHF, UHF, SHF,, etc), and *Recorded forms* – particularly the organisation of these.

Applicability of the methods was investigated in relation to: (a) Different types of educational establishment – universities, schools, etc; (b) Geographical configurations (density of establishments) – compact campus, urban school area, rural schools area etc., and (c) Geographical extent – campus, city, county, nation, continent, etc.

Model situations were evaluated for: (d) cable and recorded systems for a campus, and (e) cable, radiative and recorded systems for the schools in a county.

During the investigation of these topics many other factors were considered, including methods of use and organisation of recorded systems of distribution, cassette systems of recording and replay, both current and under development, the duration of currency of programmes in education, the consequences of common curricula and common timetabling. Related topics were class versus individual learning, community cable systems, legal problems such as wayleaves, copyright, etc., the technical performance of existing systems, limited bandwidth systems and the use of wide-band systems to carry multiple narrow-band programmes, and the costs, both capital and recurrent, of the systems investigated.

The *objects* of the survey were:

1. To advise those who have to make an immediate decision on distribution systems;
2. To help in long-term planning of systems, and
3. To inform industry of the educational needs for TV distribution and the features that practical systems should possess.

It is hoped that the report will be available from NCET early this year.

SATELLITE DIGEST – 56

A monthly listing of all known artificial satellites and spacecraft, compiled by Geoffrey Falworth. Information is based on that supplied by the Space Department of the Royal Aircraft Establishment, Farnborough, NASA, Satellite News and BIS sources. For information on the derivation of orbital parameters, abbreviations, etc., see July 1972 issue, page 262.

Continued from February issue, page 80

Name, designation and catalogue number	Launch date, lifetime and descent date	Shape and weight (kg)	Size (m)	Perigee height (km)	Apogee height (km)	Orbital inclination (deg.)	Nodal period (min)	Launch centre, launch vehicle and payload/launch origin
	1972 Sep 1.74	Cylinder	9.75 long					WTR SLC 4-West
1972-68A	29 days		1.52 dia	140	380	110.50	89.71	Titan 3B Agena D
6172	1972 Sep 30	3000?						DoD/USAF
	1972 Sep 2.74	Boom + 3 cylinders	7.32 long					WTR SLC 5
1972-69A	90 years		0.59 dia	716	863	90.14	100.68	Scout B
6173		93.89						USN/USAF
Cosmos 518	1972 Sep 15.40	Sphere-cylinder	5 long?					Plesetsk
1972-70A	8.85 days (R)		2.44 dia	204	307	72.84	89.64	
6186	1972 Sep 24.25	4000?						USSR/USSR
	1972 Sep 15.40	Sphere?						Plesetsk
1972-70C	12 days		2 dia?	200	278	72.85	89.30	
6198	1972 Sep 27							USSR/USSR (1)
Cosmos 519	1972 Sep 16.35	Sphere-cylinder	5 long?					Tyuratam-Baikonur
1972-71A	9.90 days (R)		2.44 dia	207	360	71.33	90.19	
6188	1972 Sep 26.25	4000?						USSR/USSR
	1972 Sep 16.35	Sphere?						Tyuratam-Baikonur
1972-71D	28 days		2 dia?	200	323	71.2	89.76	
6200	1972 Oct 14							USSR/USSR (2)
Cosmos 520	1972 Sep 19.81	Cylinder?	4 long?	227	669	62.88	93.52	Plesetsk
1972-72A	5 years?		2 dia?	652	39319	62.8	710.0	
6192								USSR/USSR (3)
Explorer 47	1972 Sep 23.06	Cylinder + 4 booms	1.58 long	260	237429	28.63	7349.9	ETR LC 17B
1972-73A	10^6 years		1.35 dia	201100	235600	17.23	17670	Delta
				201599	235639	17.2	17702.1	
6197		390.10		201110	235606	17.2	17671.3	NASA/NASA (4)
Cosmos 521	1972 Sep 29.84	Cylinder?	4 long?					Plesetsk
1972-74A	1200 years		2 dia?	965	1022	65.89	104.97	
6206								USSR/USSR
Molniya 2C	1972 Sep 30.85	Cylinder-cone +	4.2 long?	392	39240	65.63	703.2	Plesetsk
		6 panels +						
1972-75A	5 years?	2 antennae	1.6 dia?	551	39792	65.3	717.5	
6208		1250?						USSR/USSR (5)

Supplementary Notes:

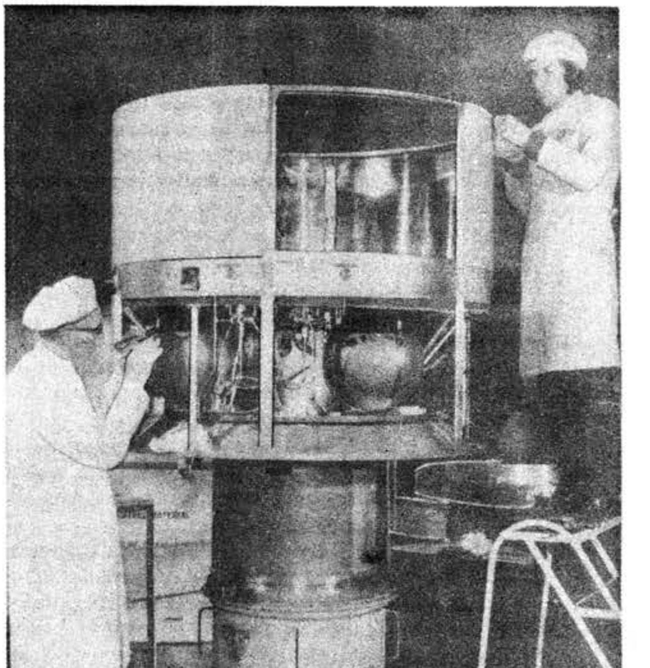
(1) Capsule ejected from 1972-70A at 1972 Sep 23.

(2) Capsule ejected from 1972-71A at 1972 Sep 25.

(3) Orbital data at 1972 Sep 20.0 and Oct 1.0.

(4) IMP H, ninth Interplanetary Monitoring Platform spacecraft, studies solar influences on Earth's environment and acquires data in support of increasingly detailed studies of Earth's magnetic tail variations during solar wind-caused disturbances, further studies interplanetary and near-Earth magnetospheric dynamics, obtains data during quiet Sun periods for correlation with previous IMP data, performs detailed and near-continuous observations of Earth's interplanetary environment during orbital periods comparable to several rotations of solar active regions, studies particle and field interactions in Earth's distant magnetotail including extensive cross-sectional charting of magnetotail and neutral sheet regions and provides a data-acquiring Earth-orbiting reference for correlation with similar data acquired by Pioneer 10 (1972-12A) and future proposed Jupiter, Venus and Mercury flyby spacecraft. Upper spacecraft structure fully enclosed by metallic upper spacecraft protective cover and side panels for radio interference and thermal control requirements holds an internal aluminium honeycomb shelf supporting onboard experimentation and associated spacecraft electronics whilst lower section holds a main axis-aligned 0.28-metre long, 0.46-metre diameter central thrust tube supporting Explorer 47's onboard integral solid-propellent high Earth orbit-circularisation rocket motor. Nominal power supplies of 130 watts at 38 volts are maintained by 2 spacecraft-encircling arrays of solar cells mounted above and one cell array mounted below the mid-section-mounted experimentation viewing area. Spacecraft telemetry using 2 transmitters and a convolutional encoder and tracking beacon transmits convolutional coded or complement coded pulse coded modulation data on command at 137.920 MHz at 12 watts, while secondary transmitter, also capable of acting as prime data transmitter, transmits range and range-rate data and special-purpose split-phase pulse coded modulation data from the spacecraft's onboard data systems engineering test unit on command at 136.890 MHz at 8 watts through 4 active and 4 passive equally-spaced turnstile antennae extending radially outwards from between Explorer 47's two upper solar cell arrays, to NASA's Space Tracking and Data Acquisition Network stations including spacecraft interrogation range and range-rate systems located at Carnarvon, Tananarive, Rosman, Santiago and Fairbanks, minitrack stations monitoring Explorer 47 during early-orbit phases during high-strength spacecraft

signal, and stations at Canberra, Quito, Rosman and Johannesburg transmitting pulse coded modulation commands to the spacecraft and providing continuous real-time data telemetry reception capability during Explorer 47's active lifetime. Prime spacecraft command receiver operating at 148.98 MHz provides ranging signal for secondary telemetry transmitter, detected pulse coded modulation signal for onboard ranging encoder, detected AM signal for the pulse coded modulation command decoder and provides for exchanges of range and range-rate data between Explorer 47 and Earth-based tracking stations, while secondary command receiver, also operating at 148.98 MHz, provides detectable AM signal for onboard sequential tone decoder. Spacecraft attitude control system uses freon 14 cold gas monopropellent thrusters mounted on 2 diametrically-opposite 1.22-metres long booms deployed from the spacecraft's lower experimentation midsection after orbital insertion providing spacecraft spin-axis orientation nominally perpendicular to the ecliptic, spacecraft rotation of between 40 and 50 rpm prior to apogee motor ignition, 20 rpm prior to experiment-boom deployment and nominal 46 rpm during remainder of the mission. Onboard optical aspect system uses a solar sensor and an Earth sensor telescope system viewing through Explorer 47's experimentation area and associated electronics providing spacecraft axis orientation data, spin rate data and onboard solar-orientation reference for boom-mounted gas-jet attitude control system. Explorer 47 in-orbit engineering experimentation includes thermal coatings engineering tests using thermistors measuring space environment-caused solar absorbency changes in temperature of 12 spacecraft-mounted sample areas including black base reference sample and transmitting temperature values to ground stations while onboard data systems engineering tests flight-qualifies high data rate-capacity data multiplex unit and data processing unit which, together with associated power converter transmits pulse coded modulation data via Explorer 47's analog transmitter. Operational efficiencies in orbit of integral glass solar cell arrays are determined by monitoring temperature characteristics and current produced by experimental integral glass solar cells for comparison with currently-used operational solar cell arrays. Explorer 47 carries 13 scientific experiments to continue studies of interplanetary radiation, solar wind and solar energetic particle emissions and magnetic fields from its high, circular, low-inclination Earth orbit. Four separate telescope systems incorporating scintillators and surface-barrier and lithium-drifted silicon detectors utilising a unique priority data system employed during intense solar flare activity overcoming relatively-low data bit rate measures solar and galactic electrons and nuclei through a solar cycle in studies of solar modulation, solar quiet- and solar flare-associated anisotropies, solar and magnetospheric charged particle acceleration processes and solar charged particle compositions. Instrumentation measures cosmic ray energy spectra, nuclear composition and electron flux over wide range of energies and dynamic flux ranges in studies of solar flare particle acceleration and particle containment in the solar vicinity. Cosmic ray particle energies, charge magnitude and sign and identification of positrons, electrons, protons, helium nuclei and carbon, nitrogen and oxygen nuclei are determined in studies of solar flare and solar event low energy particle composition and energy spectra, while 2 collimated electron detectors using a scintillator and anti-correlation scintillator mounted at right angles to each other adjacent to an associated single background detector measured energy spectra, intensity and variations associated with solar and magnetic activity in studies of solar flare-emitted X-radiation and interplanetary relativistic and non-relativistic electrons and positrons and Earth's magnetospheric shock wave, transition region, tail and boundary electron characteristics. Multi-element, totally-depleted, solid-state telescope detector with anticoincidence shielding designed to eliminate scattered electron effects measure electron and hydrogen and helium isotope differential energy spectra in studies of local particle acceleration, solar particle acceleration and interplanetary medium particle storage processes, and particle propagation and solar modulation in interplanetary space. Three-element telescope system utilising 2 side-mounted solid-state detectors measuring electrons deflected by a magnet studies solar cosmic radiation propagation characteristics over wide ranges through the interplanetary medium, electron and proton concentrations throughout Earth's geomagnetic tail and magnetopause extremities and solar cosmic ray action and effect on Earth's magnetic field by utilising correlation with data acquired by Earth-orbiting meteorological satellites. Charged particle measurements experiment measures solar, cosmic ray and magnetospheric protons, α particles, heavy nuclei and X-rays in 2 wavelengths at wide energy ranges in studies of solar-emitted particle angular distributions, energy spectra, propagation characteristics and absolute intensities of solar- and magnetospherically-streaming particles and a larger Geiger-Mueller tube measuring galactic X-ray sources. 3.05-metres long boom-mounted Faraday cup collector split about Explorer 47's equatorial plane having a modulation potential applied to one of the grids investigates plasma properties in Earth's magnetospheric tail and interplanetary space region of Earth's magnetospheric transition region by measuring electron charged particle flux energy and angular distributions in the spacecraft's equatorial plane and plasma flow properties along that plane. Onboard low energy particle detector measures low energy electron and proton differential energy spectra to distances of 40 Earth radii to acquire further data on geomagnetic storm, aurorae, magnetospheric tail and neutral shield and other magnetospheric phenomena. Ion composition instrumentation measures mass-to-charge ratios



Engineering model of COS-B, ESRO's 8th scientific satellite, at BAC's Spacecraft Assembly Building at Bristol before being shipped to Messerschmitt-Bolkow-Blohm. Three further models of COS-B will be built leading to launch of the flight unit in 1975. The 280 kg satellite, designed to investigate the intensity, direction and distribution of galactic cosmic rays, is being developed by the Cesar Consortium of which M-B-B is prime contractor. BAC is responsible for design and manufacture of the complete attitude measurement sensor and electronics system, the electronics associated with the gas flushing control and pneumatic systems and the solar arrays. The spacecraft will be the first ESRO satellite to operate from geo-stationary orbit.

British Aircraft Corporation

and energies of solar wind ions having velocities between 200 and 600 km per sec. and identifies helium and oxygen ions to study solar wind ion composition for correlation with solar corona and photosphere temperature and composition data and solar wind plasma energisation processes. Explorer 47's plasma analyser comprising hemispherical analyser plates and an electron multiplier together with associated detector electronics, voltage supplies and logic circuits capable of resolving ions at least as heavy as oxygen and identifying ion separations in energy-per-charge spectra during low solar wind ion temperatures performs comprehensive studies of electron and positive ions at orbital altitudes for correlation with spacecraft magnetometer and other data. Magnetic field sensor package, mounted on the spacecraft's second 3.05-metres long experiment boom deployed after orbital insertion comprises 3 sensors to measure vector magnetic fields in 3 dynamic ranges in studies of interplanetary magnetic fields, Earth's magnetic tail and solar wind interactions with Earth's magnetic field, while a 0.61-metre long electric dipole antenna and a 0.18-metre diameter magnetic loop antenna, both mounted on Explorer 47's 3.05-metre long Faraday cup boom, measure two electric field vector components and one magnetic field vector component in 8 discrete frequency intervals to measure electric and magnetic field components in solar wind plasma waves, magnetospheric bow shock and transition regions and in Earth's magnetic tail for correlation with other onboard particle- measuring instrumentation. Orbital data at 1972 Sep 23.1, Sep 25.6, Oct 1.0 and Nov 1.0.

(5) 23rd communications satellite in Orbita network. Orbital data at 1972 Oct 9.2 and Nov 1.0.

SPACE REPORT

A regular monthly review of Space Events and Technical Trends

SPACE-AGE ATTACK ON SOCIAL PROBLEMS

The sophisticated techniques which helped the United States land men on the Moon are now being turned toward tackling global social problems by a new organisation made up of scientists from 12 nations, writes Walter Froehlich. The new organisation, which will have its headquarters and staff of about 100 professionals near Vienna, calls itself the International Institute of Applied Systems Analysis. Participating are scientists from the United States, the Soviet Union, the United Kingdom, Japan, Canada, Czechoslovakia, France, both East and West Germany, Italy, Bulgaria and Poland. The new body is believed to be the first non-governmental, multinational organisation to attack large and complex social problems of world-wide scope.

The Institute will study the management of large communities, provision of health services for large populations, world-wide environmental and energy problems, and other matters that affect nearly all men.

The Institute came into being on 4 October when representatives of scholarly organisations from the 12 nations signed a charter in London. Because these groups will control policies and operating philosophy, the Institute is expected to be free from governmental pressures which often encourage or force researchers to aim at specific results for immediate use in a particular geographic area or for relatively narrow national interests. All information developed in the Institute's research and studies will be made available to the scientific communities in all nations.

The term 'systems analysis' in the Institute's name refers to a technique for solving complicated problems by dissecting them into their components and then employing specialists to work on each component. With the development of large and fast computers in the United States, systems analysis, also called systems engineering, grew in sophistication. It reached a peak in refinement when it was used in the US Apollo programme in the 1960's to help design equipment and techniques for sending men to and from the Moon.

The Institute's policies will be set by a council made up of representatives of the participating scholarly organisations. At its organisation meeting, the council elected Jermen M. Gvishiani, representative of the Academy of Sciences of the Soviet Union, to a 3 year term as council chairman. In charge of the Institute's operations will be a director. Elected for that position was an American, Howard Raiffa, a professor of managerial economics at Havard University, Cambridge, Massachusetts. He will move to Vienna and spend full time in the position.

In each of the first 3 years of operation, the Institute budget will be at $3,500,000 of which the U.S. National Academy of Sciences and the Soviet Academy have each pledged up to one million dollars. The rest has been promised by other institutions.

The concept for such an Institute was first suggested by the United States in 1966. At that time, McGeorge Bundy, now president of the Ford Foundation and then a special assistant to President Lyndon B. Johnson, opened discussions on the subject with representatives of the Soviet Union. Negotiations have since been under way between the U.S. and Soviet academies. Organisations from other nations joined the discussions later.

President Nixon endorsed the plans in February 1971 and, at a meeting in Paris in October 1971, representatives of scholarly institutions in 8 nations appointed committees to organise the institution. The Institute will be housed in Laxenburg Palace, 10 miles from Vienna. The palace, built in the 2nd half of the 18th century, is being renovated by the Austrian Government and is expected to be ready for occupancy this spring.

Under consideration as one of the first tasks of the Institute staff and visiting scholars is a study of the world supply of energy resources and demands for energy. This is expected to include the feasibility of substitutions among energy sources, an assessment of future technologies and their expected impact on the world energy picture, and the hazards in each source. Among environmental subjects being considered for study are water resources, air and water pollution, agricultural production, recycling of materials, prediction and control of natural disasters, and the preservation of the ecological balance.

Other potential projects are investigations of medical data handling to improve diagnosis and treatment, population control and genetic engineering, weather modification,

international problems of ocean fishing, the management of sanitation and transportation services, the design of new towns, and the phased renewal of old towns.

The 10 founding members of the Institute, besides the US and USSR Academies of Sciences, are the Committee for the Czechoslovakian Socialist Republic; the Committee for the Institute of Applied Systems Analysis of Canada; the Committee for the People's Republic of Bulgaria; the French Association for the Development of Systems Analysis; the German Academy of Sciences of the German Democratic Republic; the Japanese Committee for the Institute of Applied Systems Analysis; the Max Planck Society of the Federal Republic of Germany; the National Research Council of Italy; the Polish Academy of Sciences, and the Royal Society of London.

Scholarly organisations from other countries are expected to join the Institute within the next 3 years. Elected as vice chairmen for the Institute were Maurice Levy of the French Association for the Development of Systems Analysis and Dr. H. Koziolek of the German Academy of Sciences of the German Democratic Republic.

LIFE FORMING MOLECULES IN SPACE

Australian scientists have recently made a number of discoveries which point to the possibility of life in outer space. Using the 64 metres radiotelescope at Parkes, New South Wales, radiophysicists with the Australian Commonwealth Scientific and Industrial Research Organisation (CSIRO) have detected a number of organic compounds in space which form the building blocks of life as we know it.

The discovery of these life-forming molecules in gas nebula stregthens the possibility that, given the right environment, some form of life does exist on planets other than Earth. The CSIRO scientists are now seeking more and more complex molecules which will provide further clues in the search for extraterrestrial life. The search is headed by Dr. Brian Robinson, Head of the Cosmic Radio Astronomy Group of the CSIRO's Radiophysics Division.

The organic compounds can be detected by radiotelescope since molecules emit radiation at a particular frequency as a result of their rotation. In this way scientists in the US detected formaldehyde in space in 1969. This discovery was significant as formaldehyde contains the carbon atom, one of the important building blocks of life.

In recent months Australian scientists have discovered the more complex molecules of thio-formaldehyde, acetyaldhyde and methylemine. The importance of the discovery lies in the fact that methylemine (CH_2NH) and formic acid ($HCOOH$), one of the compounds previously discovered, contain the same proportions of elements as glycine ($CH_2\ NH_2\ CO_2\ H$).

Glycine in turn is an amino acid and groups of amino acids form protein, a compound round which most forms of life as we know it revolve.

The radiophysicists have now turned their attention to the search for glycine or some similar compound but,before doing so,they need to know the frequency of the radiation emitted.

Two chemists at Monash University in Melbourne, Victoria, Professor Ron Brown and Dr. Peter Godfrey, are attempting to find the answer by synthesizing glycine in a laboratory. The most fruitful sources for these compounds so far have been the constellation of Sagittarius B_2 near the galactic centre, and the Orion nebula, which is comparatively near the Sun.

The Parkes radiotelescope, being only 4° off the galactic centre, is ideally placed to scan these sources. Observations can be made for up to 9 hr. a day compared with about 2 hr. a day for the major radiotelescopes of the Northern Hemisphere.

The work of the Australian scientists has been facilitated by the unexpected efficiency of the Parkes telescope, which is claimed to be by far the most accurate and versatile radio astronomical instrument in the world. The telescope was originally required to operate at a wavelength of 21 centimetres (cm) and designers hoped that it would operate down to wavelengths of 10 cm. It has been found that,with minor improvements,the instrument will operate effectively down to wavelengths of 1 cm.

The Parkes telescope is expected to be even more effective in the search for life in space when a new digital correlator is brought into operation. The correlator, now undergoing trials, was designed and built at the CSIRO Radiophysics Laboratory in Sydney and will provide 1024 channels, compared with the present 64, which will produce finer detail in resolving the radio lines.

BRITISH SPACE GLASS

A British firm has four orders and is currently negotiating for others, which together could total £1 million, to supply special glass for international satellite programmes. The glass, developed for Pilkington's optical glass division by the group's Birmingham-based subsidiary Chance Brothers, is used in ESRO 4. It covers the satellite's solar cells, giving them a longer life in space through increased protection from harmful radiation. In all there are 8,500 of the special covers, which are about the size of a postage stamp and only a few thousandths of an inch thick.

Now the covers, processed by Pilkington PE at St. Asaph, have been specified for a major American manned spacecraft. PPE expects to supply 1,700,000 covers to the USA during the next 3 years.

Five thousand covers are at present being supplied for the Intasat satellite developed by Spain. A similar order has been received for ANS, a satellite to be launched for Holland. Orders to supply 35,000 covers for a new ESRO space project and 50,000 covers for the huge Canadian technology satellite are in the pipeline. Talks to supply German and Italian space ventures have also taken place.

Satellites use the solar cells to convert light from the Sun into electrical power but the cells need covers to protect them from radiation. Any reduction in the transparency of the covers, however, has an adverse effect. The covers include cerium oxide in the basic glassmaking mix and this has solved problems of discolouration, caused by radiation, which significantly reduces the cell's efficiency.

The glass is made from a formula evolved after six years of experiment by Pilkington scientists. Designated CMS, ceria-doped glass provides a highly emissive surface which efficiently radiates waste heat. The covers are light, cheaper, more reliable and have a longer life than conventional types.

Pilkington sought to develop a glass with in-built anti-radiation properties and to dispense with the expensive and vulnerable coatings, of which there are sometimes as many as 17. It was found that the addition of 7% cerium oxide in the glassmaking mix had the right effects. The glass was not

discoloured by radiation and the elimination of the multi-layer coating considerably reduced the chances of failure due to delamination and made cheaper manufacture possible.

The only coating which is needed is vacuum deposited by Pilkington PE. That coating,which is common to all solar cell covers,is a layer of magnesium fluoride which acts as an anti-reflection agent in order to improve the glass's transmittance for the light which is required by the solar cell.

PIONEER 10 THROUGH ASTEROID BELT

The Pioneer 10 spacecraft, bound for Jupiter, seems to have crossed the Asteroid Belt without incident, reports the Ames Research Center. Though numbers of the larger projectile-like asteroid particles observed may be somewhat higher than expected, it appears that the belt will offer no serious hazard to spacecraft passing through it on future Outer Planets missions.

On 30 October, at about the belt's midpoint, Pioneer 10 was 434 million km (270 million miles) from the Sun, nearly half way on its trip to Jupiter. The 270 kg (570 lb.) space-craft is the first to fly beyond the orbit of Mars, the first to penetrate the Asteroid Belt, the first intended to make close observations of any of the Outer Planets, and the first destined ultimately to escape the Solar System into inter-stellar space. Launched on 2 March 1972, it entered the region of the Asteroid Belt in mid-July, should emerge this February, and is scheduled to fly by Jupiter in December.

The main part of the Asteroid Belt occupies a doughnut-shaped region encircling the Sun between the orbits of Mars and Jupiter. It is about 280 million km (175 million miles) across and about 80 million km (50 million miles) thick. The material in the belt is thought to range in size from dust particles to rock chunks as big as Montana,orbiting the Sun at speeds of around 72,000 km/hr. (45,000 m.p.h.).

The vast majority of the asteroid particles are believed to lie in 1 mm (.04 in.) to 1/100th mm size range. Bodies above 1 cm (0.4 in.) in diameter are believed to be extremely rare. Particles as small as 2 to 4 mm in diameter, travelling at average speeds of 54,000 km/hr. (34,000 m.p.h.) relative to the spacecraft, can penetrate 1 cm (0.4 in.) of aluminium and could cause significant damage to spacecraft.

Briefly, Pioneer 10's observations of particles so far are these:

(a) In the very small size range, 1/10 to 1/100 mm diameter, fewer particles than expected have been encountered. There has been virtually no observed increase of these small particles in the Asteroid Belt.

(b) For the larger particles, 1/10 mm to 1 mm in diameter, 6 more months of data analysis will be needed to make definitive statements. However, quick-look data suggest that these particles may be somewhat more numerous than some previous estimates.

(c) Up to 20 October, the NASA Langley Research Centre gas cell experiment (which measures principally particles in the 1/10 to 1/100 mm range) had reported a total of 83 penetrations of its 234 cells. The rate of penetration had been almost constant since launch.

William Kinard, the gas cell experimenter, comments that his instrument has failed to see several expected phenomena. 'We expected to see the rate of particle penetrations diminish as we left Earth's orbit and travelled to the edge of the Asteroid Belt. We have no evidence of this. We see no evidence of Earth or Mars sweeping out particles in their vicinity of space. We have not seen an expected 10 time increase in particle penetrations in the belt.

The constant penetration rates that are being experienced by the instrument tend to indicate that all of the particles in the size range which the instrument detects have a common origin. This is probably cometary debris, though there are other explanations. We had expected to see cometary particles early in the mission and asteroidal particles in the belt.

'If the penetration rate remains constant, some portion of our 234 gas cells will last for 8 to 10 years, giving us good data far beyond Jupiter. We had thought we would lose most of our cells in the Asteroid Belt '.

In contrast to the gas cell experiment, the General Electric asteroid-meteroid telescopes observe more particles in the larger size ranges. The telescopes can see a .5 mm sand-gain-sized particle as far as 10 metres (33 ft.) from the spacecraft, a 5 mm pea-sized particle out to 100 meters (330 ft.), and a 4 cm ping-pong ball-sized particle out to about 1 km.

The telescope experiment can be used to determine the speed and direction of the particles and can infer their size. Because of its complexity, a long time is required for data reduction and interpretation. However, quick-look data based on only part of the observations by the telescope experiment, indicates that its 4 telescopes have seen between 100 and 200 particles since launch.

In one region, sightings of these larger asteroid particles appear to have increased in number for a week or more and then decreased again. Quick look data indicate that this region of temporary increase in sightings coincided with one of 2 known regions of maximum density for the large asteroids which are visible by telescope from Earth. This region lies at about 400 million km (250 million miles) from the Sun. The second such region is at about 480 million km (300 million miles) from the Sun.

International Co-operation for Space Broadcasting

Concluded from page 109]

A regional tele-education system, implies a large degree of common programming by participating countries. The problems in reaching agreement on such questions as educational structures, curricula, programme production and scheduling are certainly formidable, But the goal of quality teaching in schools at all levels and in all areas, and of information and continuing education programmes for adults, makes the attempt worthwhile. Success must be founded on a high degree of adaptability, co-operation, goodwill and mutual confidence.

BOOK REVIEWS

Edited by L. J. Carter, FBIS.

Astronautics and Aeronautics, 1969: Chronology on Science, Technology, and Policy.
By Science and Technology Division, Library of Congress, NASA, 1970, Vol. II, 534 pp. $2.25.

The bulk of this volume is a straightforward daily chronology, gleaned from announcements by agencies, companies, periodicals, newspapers and other sources. The coverage is wide: almost every day has at least one item: the important, the insignificant, and all points between. There are also appendices listing launchings, and an index running to 59 pages.

1969 was the biggest year in space so far. It saw 4 Apollo flights, 5 Soyuz flights, and 2 Mariners – but also many lesser things, often fascinating. For example: an atheist campaigner sued NASA, objecting to astronauts practising religion on duty;

11 crew won medals under the will of a Frenchwoman who died in 1891 leaving provision for the award to the first person to contact a heavenly body, Mars excluded!

Particularly interesting are the quotations from a variety of people, some showing vision (e.g., Arthur C. Clarke), others depressingly short-sighted (e.g., Lewis Mumford and C. P. Snow).

It is frank for an official publication, e.g., it gives some space to the test pilots v scientists controversy in NASA.

It is ironic to read now that, in 1969, NASA's schedule set Apollo 18 in February 1972 and Apollo 19 in November 1972, with three preparatory flights for the first space station between them!

Errors include: p.93, caption, 'Mariner IV' should read "VI'; p.150, 'Third ATS' should read 'Fifth'; p. 157, 'citing' should read 'sighting'; p. 466, 'Schweikart' should read 'Schweickart'; p. 46 'Garbatko' should read 'Gorbatko'; on p. 261 a whole line of type has been misplaced 8 lines; and on p.471 a periodical title is printed upside down! Also, on p. 247 a newspaper is quoted as referring to 'Mars, 5 million miles away', and on p. 318 Dr. Paine is quoted as saying 'our little 8,000-mile-diameter Solar System' (an error for 8,000,000,000 miles?).

An irritating feature is the welter of abbreviations which fill the pages. It is annoying to have to keep turning to the index, which does not explain all those used anyway. A separate list would be better.

'A chronology is but the first step towards history' says Eugene Emme in his preface. This one is brilliantly compiled, and provides a fascinating framework of facts for anyone interested in space.

RAYMOND WARD

Physical Studies of the Minor Planets
Ed. By T. Gehrels, US Govt. Printing Office, 687 pp, 1972, $3.00.

With the flight of Pioneer 10 through the asteroid belt on its way to Jupiter, the study of the minor planets, which forms the subject of this book, takes on a new interest of no longer a purely academic nature.

This substantial volume is based on papers presented at an international conference held in March 1971; the 12th Colloquium of the International Astronomical Union. The book also includes several pages which did not appear at the IAU conference owing to time limitations. The complete work forms an impressive record of modern thought on the study of the minor planets and,as such,satisfies a long-felt need for an up-to-date review of the subject.

The contents are divided into three sections: Part I – Observations; Part II – Origin of Asteroids, Inter-relation with Comets, Meteors and Meteorites; Part III – Possible Space Missions and Future Work. Faced with the task of reviewing a work of this nature, feelings of trepidation are commonly experienced, but in this particular case such fears were unfounded. The book is presented in an easily-digestible style with many excellent diagrams and illustrations, comprehensive lists of references and a useful index.

The fact that a variety of authors are represented and many facets of study explored should help to make the book of interest to readers of all levels of knowledge. There is much advanced work reported, which requires some effort to understand, but there are also many papers included of a more general, descriptive nature and which the educated layman would have little difficulty in assimilating.

This reviewer found the section on the exploration of the asteroids by spacecraft of particular interest. Space missions, both manned and unmanned,are discussed in some detail, three papers being devoted to those aspects of the American Pioneer 10 mission which are related to the study of the minor planets.

In the final paper of the book, the Editor, Tom Gehrels of the University of Arizona, suggests areas in which future work might be carried out, and makes a special plea for greater involvement by scientists in the early stages of spacecraft mission planning, as well as for renewed efforts to discover more comets and asteroids.

In conclusion, the work can be recommended both as an up to-date review of ideas on the minor planets and their exploration, and possibly as the standard work on the subject for many years to come.

J. L. BALL

The Story of Astronomy
By Patrick Moore, Macdonald, 1972, 253 pp. £2.95.

Astronomy is becoming so diversified as a science that it is often essential to gather together its specialist fields. Astronomy is the oldest science,with a great history,and it cannot be effectively pursued without having an overall appreciation of the subject. Fostering that appreciation is an art, which finds display on the popular shelves of bookshops, so the books that lure the gift-buyer should also insprire a professional readership, which is always prone to lose sight of the wood for the trees.

This type of overall survey has been given a classic treatment in this fourth revision of a book which has hitherto gone by the title of 'Astronomy'. Although this edition brings the work up to Apollo 16 and Mariner 9, it does little to alter its basic appeal which continues to lie in its beautifully illustrated historical approach.

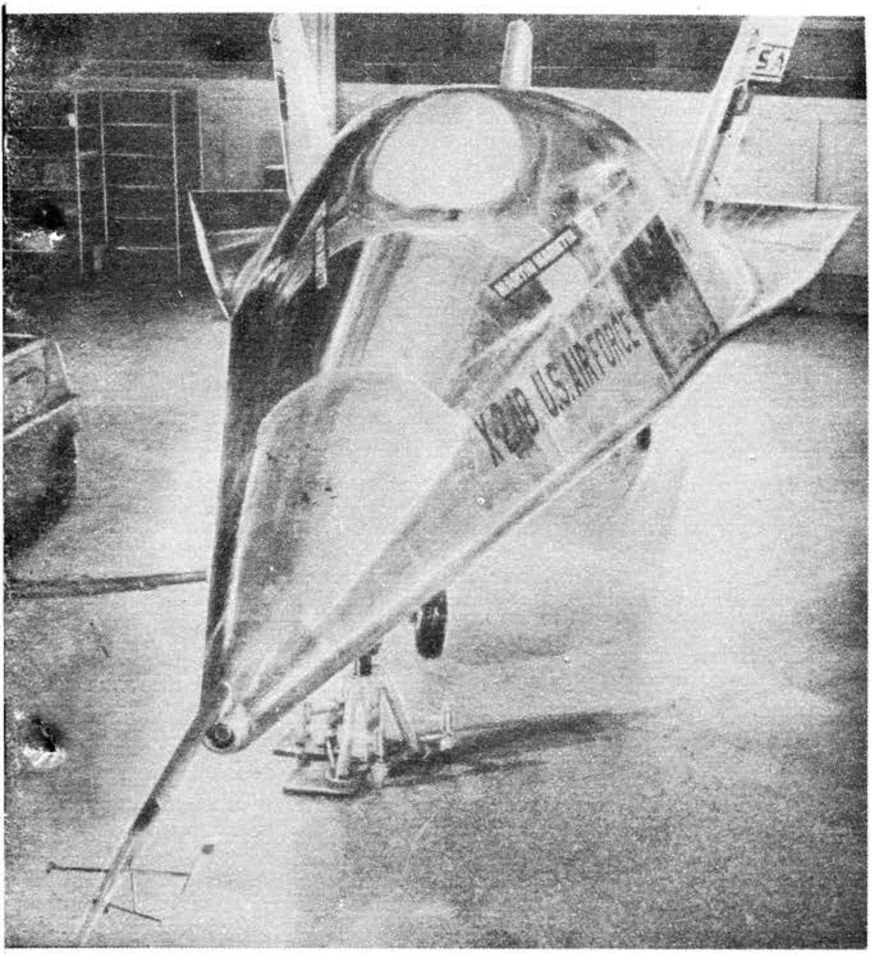
One should really buy two copies of this book; one to read, the other to dismember, for many of its illustrations are suitable for framing.

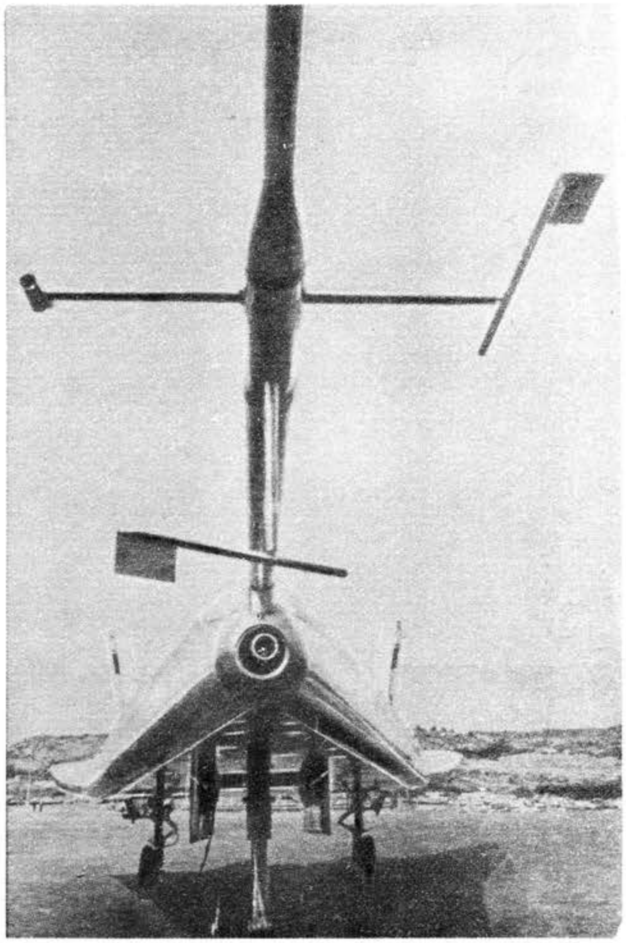
M. J. ANSLOW

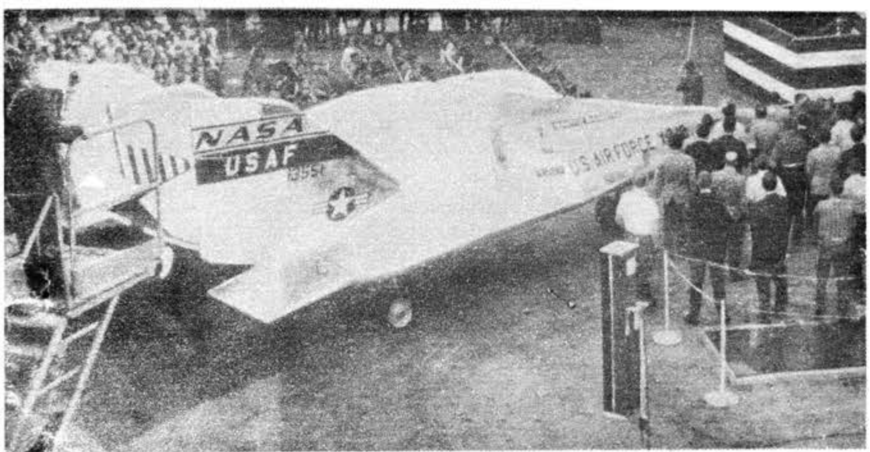
SPACEFLIGHT

88905 КОСМИЧЕСКИЕ ПОЛЕТЫ № Т-4
(спейсфлайт)
По подписке 1973 г.

Volume 15 No. 4 April 1973







Published by The British Interplanetary Society

SPACEFLIGHT

A Publication of The British Interplanetary Society

Editor:

Kenneth W. Gatland, FRAS, FBIS

Assistant Editor:

L. J. Carter, ACIS, FBIS

VOLUME 15 NO 4 APRIL 1973 *Published 15 Mar 1973*

CONTENTS

COVER

SPACE BIRD. The advanced lifting body X-24B will make its first flight from a modified B-52 within the coming weeks. Built for NASA and the USAF by Martin Marietta on the basis of the X-24A airframe, its purpose is to extend research in the handling, stability and performance of piloted lifting bodies from approximately 1,000 m.p.h. (1 609 km/hr) down to landing speed. After separating from the mother plane at 45,000 ft. (13 716 metres), it will be boosted to 60,000 ft. (18 288 metres) by its liquid propellent rocket engine. Thirty flights are planned. See page 150.

Martin Marietta

MILESTONES

Jan

19 Dr. Rocco A. Petrone, formerly director of Apollo programme at NASA Headquarters, becomes director of Manned Space Flight Center, Huntsville, Alabama, succeeding Dr. Eberhard F. M. Rees who has retired.

19 Academician Andrei Severny, director of Crimea Astrophysical Observatory, reveals that Lunokhod 2 carries an astrophotometer, an electron telescope without lenses which registers glow in wide areas of the sky both in visible and ultra-violet spectral bands.

19-20 Lunokhod 2 moves farther away from landing site for 2½ hours in south-easterly direction over basalt lava and negotiating craters and boulders. Speed is nearly twice that of Lunokhod 1. Total distance covered is 1,148 metres, ending 1,050 metres from Luna 17 landing stage. Pressure and temperature within instrument compartment 800 mm of mercury and 20°C respectively. Panoramic pictures clearly show mountains bordering Sea of Serenity.

24 NASA announces that ground testing of Skylab will delay launching from 30 April to mid-May at the earliest. Firm launch date to be given after completion of Flight Readiness Test at end of March.

26 Lunokhod 2 is parked for lunar night on the edge of a crater, more than 1 km from Luna 21 landing stage.

29 In FY 1974 Budget request submitted to Congress President Nixon, $3,136 million is requested for NASA, an increase of $74 million or nearly 2.5%. Amount allows space agency to begin work on two new projects, an advanced version of the Nimbus weather satellite to monitor air and ocean pollution (one launch each in 1974 and 1977), and a Terrestrial Reference satellite for launch in 1976 'to permit laser beam measurements of distances between locations of different continents to an accuracy of a few inches for determination of small movements of land masses'.

Feb

2 ELDO Council in Paris defers final decision on fate of Europa II until further meeting scheduled 31 March. France still wishes programme to continue in order to launch communications satellites but West Germany desires to leave launcher programme.

9 Lunokhod 2 begins second working day. Warm-up lasts 20 minutes after opening of solar panel. Temperature within instrument compartment exceeds 22°C; pressure 780 mm of mercury. First action is to survey supposed meteorite crater with vehicle using magnetometer on 2.5 metre arm to measure magnetism by approaching crater from four sides. Lunokhod made 120 turns and travelled 364 metres, during which vehicle sank into loose soil up to its wheel hubs.

9 NASA announces that U.S. Astronaut team for Apollo/Soyuz docking mission in July 1975 will be Thomas P. Stafford, Donald K. (Deke) Slayton, and Vance D. Brand.

11 In a single session of exploration, Lunokhod 2 covers 1636 m. in a Southerly direction. Vehicle stops more than 3 km from Luna 21 landing stage.

SPACE PROBE FROM EPSILON BOÖTIS

By Duncan A. Lunan, M.A.

The astonishing idea that our Solar System had been visited by a space probe from another civilization was widely reported in December. The theory stems from original work by Mr. D. A. Lunan, a graduate of Glasgow University, who found that certain long delayed echoes of equally spaced radio signals transmitted from Earth could be interpreted in the form of a code. The data used by Mr. Lunan are those recorded in the 1920's by Norwegian, Dutch and French experimenters, who noted that delay times of the echoes varied from one signal to the next. This paper, which attempts to interpret the patterns so formed, suggests that a space probe in the vicinity of the Earth may have been trying to make contact by returning our own signals. It is suggested that the signals of October 1928 were star maps, identifying the probe's origin as the double star Epsilon Boötis and putting its arrival here at 13,000 years in the past. Although more evidence is required to support this hypothesis, the logic of Mr. Lunan's work is of interest in its own right as a contribution to the problem of interstellar communication. We leave the reader to decide for himself: (a) the reality of the long-delayed echoes as anything but a purely natural phenomenon; and (b) the validity of the interpretation that has been placed upon them.

Kenneth W. Gatland

The space probe hypothesis was first advanced by R. N. Bracewell of the Radio Astronomy Institute, Stanford University, USA, in a paper published in *Nature* in 1960 [1]. He suggested that if advanced communities were spread through the Galaxy at distances of 100 light-years or more, unmanned space probes might be the most effective means of communication between them. On entering our Solar System such a probe might listen for our radio signals and repeat them back to us. The returned signals would appear to be 'echoes' with delays of several seconds or minutes, such as those reported in the 1920's. If we returned the signals to it again, it would know it had established contact with intelligence. 'Should we be surprised,' Bracewell wrote, 'if the beginning of its message were a TV image of a constellation?' The space probe hypothesis was taken further by James Strong (*Flight to the Stars* [2]), who suggested that the probe might still be here, orbiting the Earth in a Moon Equilateral position.

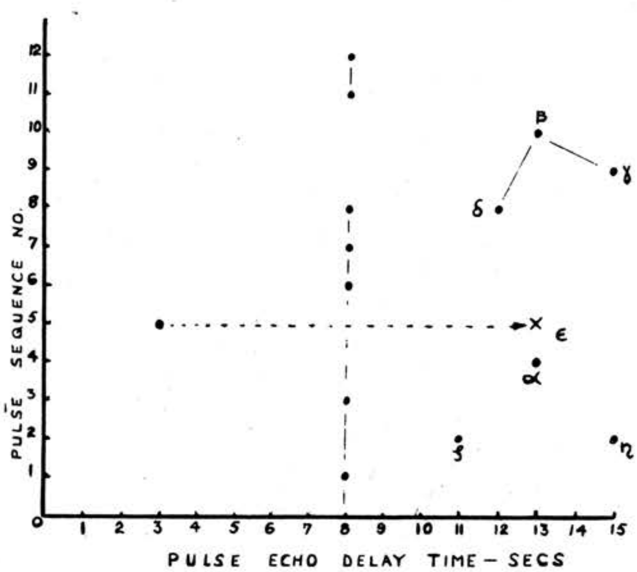
It appears that the first announcement of long-delayed echoes came from the American experimenters Taylor and Young [3]. They reported that in 1927, while listening for ionosphere echoes from around the world, they had detected echoes apparently coming from distances of 2900 to 10,000 km. The delay times were of hundredths of a second and the distances agree well enough with the dimensions of the inner Van Allen belt to suggest that the echoes had some natural explanation. In December 1927, however, Professor Carl Störmer of Oslo happened to meet by chance one engineer Hals, and mentioned the Taylor-Young results in conversation. Hals told him that he had heard echoes of 3 seconds' delay on signals from the Philips experimental station PCJJ, at Eindhoven in Holland. Hals suggested that these echoes came from the Moon [4].

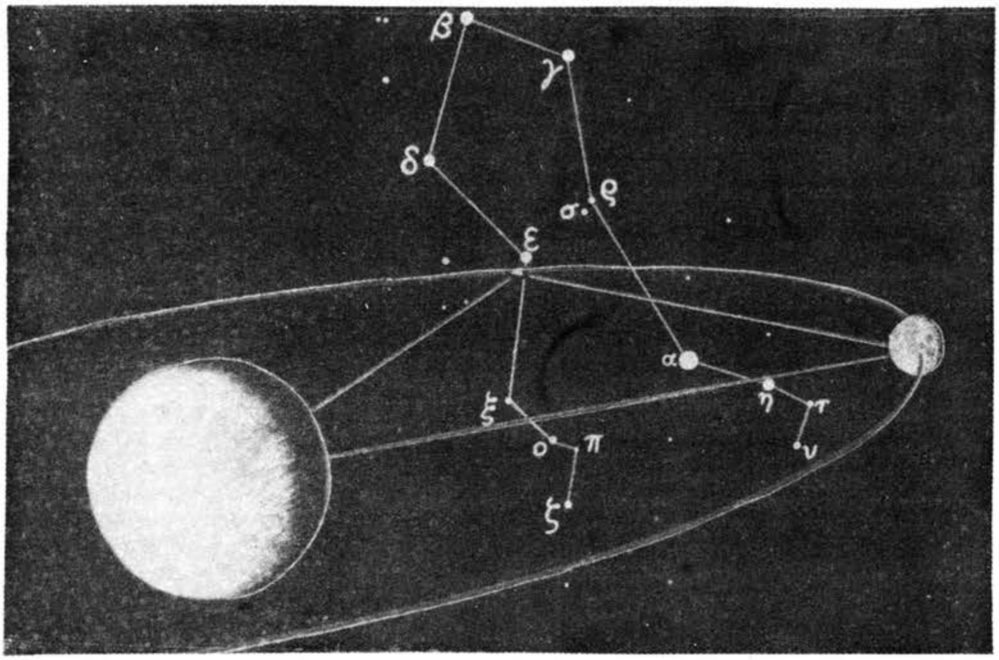
Störmer believed that the echoes came from toroidal surfaces formed by electrons moving within the Earth's magnetic field. He arranged a series of experiments in early 1928, but no conclusive results were obtained. With the help of Van der Pol in Eindhoven more tests were arranged, starting on 25 September 1928, and on 11 October Hals telephoned Störmer and announced that he was receiving 3-second echoes on signals of 31.4 metres wavelength. Störmer at once went to Hals' home, about 10 minutes away, and soon after he arrived the echo times began to vary. Caught by surprise, Störmer was not able to time the echoes accurately (see later) but noted delay times over the next 15 minutes ranging from 3 seconds all the way to 15 seconds. By arrangement with Van der Pol, the signal pulses were being transmitted at 20 second intervals so that the echoes belonging to a particular signal could be identified [5].

Störmer immediately informed Van der Pol, by telegram, that long-delayed echoes had been heard. Van der Pol repeated the test transmissions the same evening, sending 3 dots in rapid succession at 30 second intervals. He heard a sequence of echoes with the following delays: 8 seconds, 11, 15, 8, 13, 3, 8, 8, 8, 12, 15, 13, 8, 8. In 2 cases 2 echoes were heard, 4 seconds apart, and the 3 dots of the original signal were blurred into a dash in every case except that of the 3 second echo, when they came through very clearly. The frequency of the echoes was always exactly that of the signal. [6].

If these echoes were returned to Earth by a space probe, it seems incredibly unlucky that it should have happened at a time when they were assumed without question to be natural phenomena. It seems still more unfortunate, as Morrison pointed out [7] in 1962, that the hypothetical probe did not send back 'something unmistakably meant to attract attention'.

Fig. 1. First Van der Pol Sequence, evening 11 Oct. 1928: tentatively identified as an incomplete map of Boötes. This diagram can be interpreted as demanding an intelligent reply. By moving the 5th pulse (delayed 3 sec.) to a position where it is delayed by 13 sec. (marked X) the constellation Boötes is completed. This is the required answer and if transmitted back the probe should transmit further information. Note the 8 sec. 'barrier' dividing the diagram into two parts. The position of α Boötis – 'Arcturus' – can be interpreted as tentatively identifying the map as compiled some 13,000 years ago.





Space probe from Epsilon Boötis circles the Earth in an equilateral configuration with Earth and Moon (with Epsilon Boötis beyond) in this artist's impression by Ed. Buckley.

Perhaps – probably, even – it would not occur to a probe's designers that anyone would take 'echoes' with a 3 second delay for a natural phenomenon. The return of the 1927 signals, without variation, could have been a mere announcement of the spacecraft's presence: 3 second echoes, without Doppler shift, constitute a statement: 'Here I am in the orbit of your Moon'. If all the echoes ranging from 3 to 15 seconds were returned by the same object, therefore, the statement made has to be something more elaborate: the variation of delay time should surely carry some kind of meaning.

The sequence of delay times reported by Van der Pol does not show any numerical pattern. Bracewell's remark about constellation figures, however, gave me the idea of graphing the delay time of a particular echo against its position in the sequence. I first tried a graph with delay time on the y-axis (the system used by all the 1920's experimenters who presented their results graphically) and found nothing of any significance.

When delay time is used as the x-axis of the graph, however, the result is very different (Fig. 1). There are 2 possible ways to represent the double echoes, on the same horizontal line or on consecutive lines; the former system appears to be correct and I have followed it with all the other signals I have been able to trace. On looking at the graph, it is immediately clear that the 8 second echoes form a vertical barrier; the 3 second point is isolated on the left. To the right of the barrier there is a figure with a striking, but incomplete, resemblance to the constellation Boötes. When the 3 second point is transferred from the left of the barrier to a corresponding position on the right at X, it completes the constellation figure by marking the position of the star Epsilon Boötis. It seems clear that if this interpretation is correct, then Epsilon Boötis was the origin star of the probe, and had we returned the map to it with the puzzle completed, the probe's full contact programme would have been initiated.

It might seem absurd to make up a signal of delay times – like a telegram containing only the word 'stop', at varying intervals – but, once thought of, the system has certain advantages for interstellar communication by proxy. It is a more efficient way to end pictures than, for example, a dot-dash sequence in which every dash, or every dot, is to represent a blank square on a grid; and the message carried by variable delay time is less likely to be garbled in transmission. As a way of turning a given set of evenly spaced pulses into a message, varying the reply time might even seem obvious to the designers of the probe. Mr. Tom Renwick has suggested that the repetition of the 3 pulses of the original signal, in the 3 second echo and none of the others, may have been to help identify Epsilon Boötis by reference to the 3 evenly spaced 6th-magnitude stars, W,R and A570, nearby in the constellation.

One or two objections might be raised to the identification of the Boötes figure. The most serious appears to be that α Boötis (Arcturus) appears well above and to the left of its true position. At first I thought the displacement of Arcturus might be due to a stopwatch error during the Eindhoven experiment, but soon a more significant possibility occurred to me. Arcturus has one of the largest known Proper Motions, 2.29 seconds of arc per year (the apparent diameter of the full Moon in 800 years) directed to the south-west. It seems then that the probe arrived here some thousands of years ago, compiling its star map at the time; with its mission programme completed, it then became quiescent until re-activated by the ionosphere reflection test transmissions after the invention of radio on Earth.

(It would be difficult to date the probe's arrival accurately by the displacement of Arcturus. As well as its angular Proper Motion, Arcturus has a large radial velocity component directed towards the Earth, with the result that its angular motion each year is greater than the year before. In 1881, Flammarion gave its Proper Motion as 2."25 p.a. [8]. The

displacement of Arcturus in the diagram is 6 or 7 degrees from its present position, and the limited accuracy of the diagram makes it hard to estimate more accurately. Assuming a mean Proper Motion of 2" p.a. over the period, a 7 degree displacement would put the probe's arrival 12,600 years in the past – and the next map received gives reason to think that value is approximately correct).

The apparent age of the map may have a bearing on another point: of 10 fourth-magnitude stars within the confines of the diagram, ζ Boötis is the only one shown. Most historical observers over the centuries since Hipparchus have noted the apparent magnitude of ζ as 3, though in 960 and 1430 A.D. it was given as fourth magnitude, as it is today. We must also ask why α and β Coronae, at magnitudes 2 and 2½, were not included in the diagram: the most likely explanation is that to include those stars, without obscuring the junction of the vertical 8 second barrier, would have involved prolonging the delay times to beyond the maximum of 20 seconds imposed by the signals from Earth.

The use of the second as a unit of time, by a space probe from a remote star, certainly requires some explanation, but in this particular context an explanation is not hard to find. The first transmissions from Eindhoven were of 3 pulses, spaced over 2 seconds, and broadcast at 5 second intervals – too short for the probe to do anything with them other than announce its presence. When the spacing was increased to 20 seconds to make identification of the echoes easier, the probe was then able to select suitable material to transmit by the varying-delay method. In preparing that material for transmission, it had to select some suitable fraction of 20 seconds as the unit of time for the x-axis; and the unit chosen was the second, or one near enough to be taken for a second as the echoes were timed by ear and stopwatch. It is very interesting that when the separation between pulses was increased to 30 seconds, on the evening of 11 October 1928, the probe did not respond immediately to the broadened time-base but continued to use delay times ranging from 3 to 15 seconds. Eindhoven continued to transmit pulses at 30 second intervals, however, and in the probe's next transmission, on 24 October, echoes ranged over the full time-base from 3 to 30 seconds.

On 24 October, 48 echoes were received at Oslo, some of which were heard almost simultaneously on 2 receivers at Eindhoven, so confirming the reality of the phenomenon. These results too were announced by Van der Pol in *Nature* [6], but only part of the sequence was published, 21 echoes in all. The diagram in question, with delay time on the y-axis, was reproduced in many scientific publications at the time and in Störmer's book *Polar Aurora* (Fig.2), but nowhere, alas, was the sequence given in full.

When the 21 echoes are redrawn with delay time on the x-axis, it seems clear at once that the map, if it is a map, covers a much larger area of sky than that of 11 October (Fig. 3). The distinctive figure which first catches the eye resembles the 'keystone' of the constellation Hercules, represented by the dots from 13 to 21 seconds. Two nearby fourth-magnitude stars appear, namely Xi and Omicron Herculis, apparently to aid the identification; and with that help, it becomes possible to identify the first, second and third-magnitude stars within the boundaries of the map. Once again, all the first, second and third-magnitude stars are shown. One other fourth-magnitude star appears, Omega Herculis, which helps to identify α and β Serpentis Capitis.

When a tracing of the constellations is laid over the diagram, it proves necessary to rotate it to bring all the star-points successively into alignment (making some allowance for Proper Motion). Since the probe was trying to represent a large area of the curved heavens with straight reference lines, some device such as rotation would have to be employed. Four points marked A, B, C and D cannot be identified with any stars; it turns out, however, that A is the point about which the rotation must be performed. The vertical line through B and the line CD mark the limits of rotation required; and the point A proves to be the position of the North Celestial Pole, near Vega, about 13,000 years ago. Most impressive of all, perhaps, the line

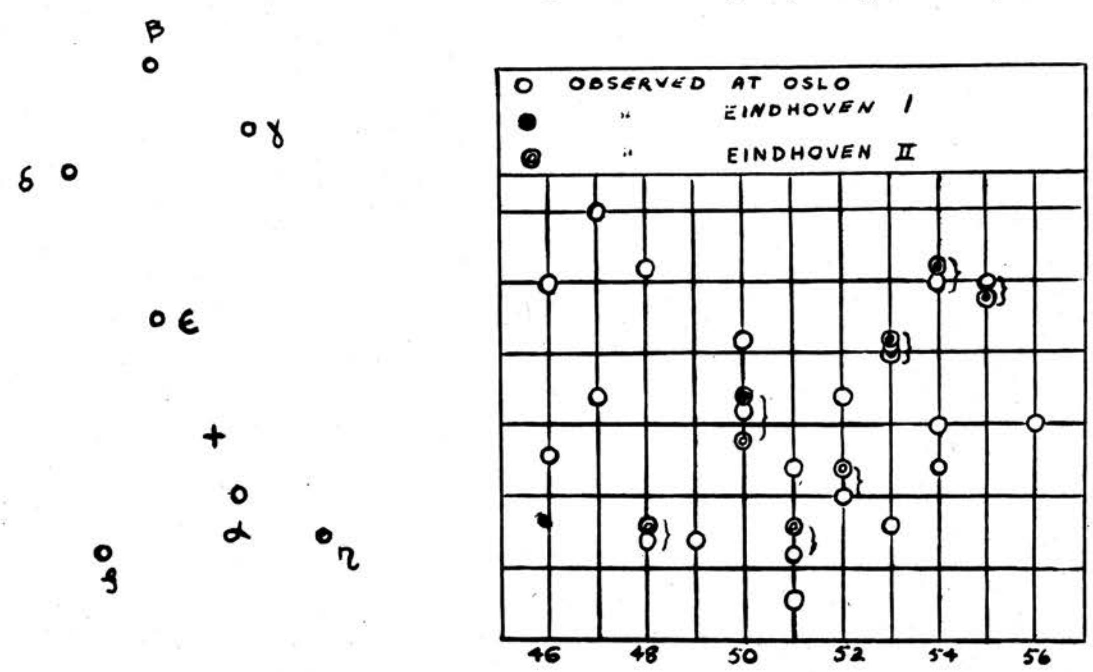


Fig. 2. (a) is the constellation Boötes from Norton's Atlas Epoch 1950. + marks the position of Arcturus (α Boötis) approximately 13,000 years ago.
Fig. 2 (b) is a reproduction of the published part of the 24 Oct. 1928 sequence from 'Polar Aurora'.

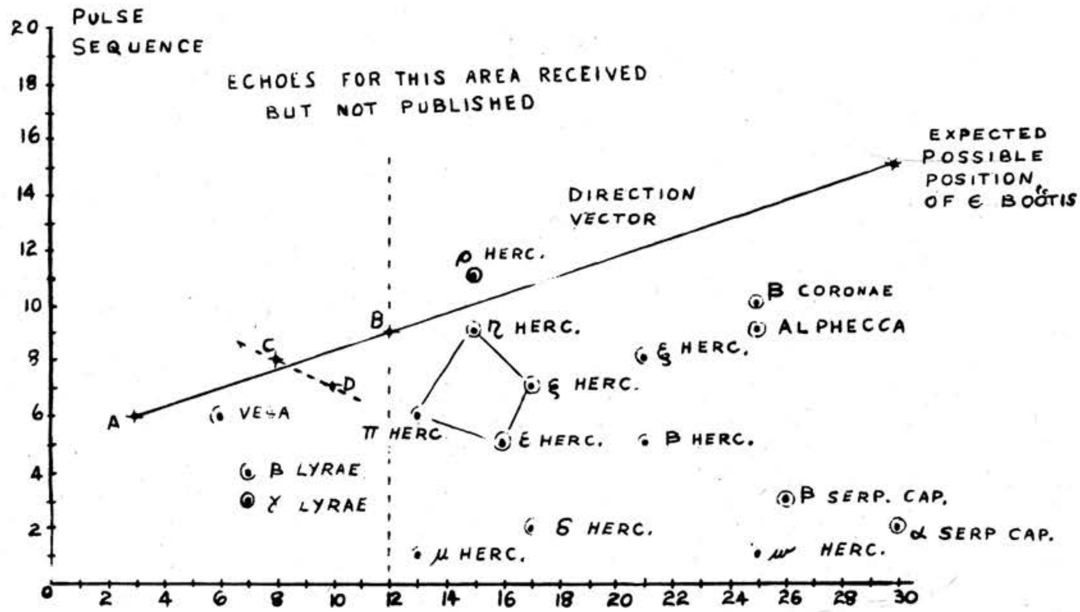


Fig. 3. The published part of 24 Oct. sequence with tentative star identifications. In this hypothesis Epsilon Boötis * should be pulse number 15 with an echo delay of 30 sec. Star pulses are marked ● and vector pulses ✦. Point A is the north celestial pole 13,000 years ago; the line through A – B points to Epsilon Boötis. The vertical line B at 12 sec. and the vector C D mark the rotation limits to align the curved celestial area with a straight line map. The unpublished sequences should cover areas of Boötes. Ursa Major, Canes Venacti, Leo and possibly include further reference points and vectors.

AB points towards Epsilon Boötis. If we had the complete map, assuming that the 21 published echoes are the first part of the sequence, Epsilon Boötis would be represented by the 25th of the 48 echoes, signal No. 60 in Van der Pol's notation.

My attempts to obtain the rest of the 24 October sequence have so far been unsuccessful. If the records can be traced, however, they will provide an important test for the interpretation of the signals. The remainder of the sequence should represent the stars of Boötes, Ursa Major and Canes Venacti, plus more reference points or, depending on the amount of further rotation involved, some of the major stars of Leo.

With the information we now have, a very tentative attempt can be made to interpret the echoes heard on the afternoon of 11 October. Störmer recorded 4 sets of echoes over a period of 15 minutes, as follows: 15 seconds, 9, 4, 8, 13, 8, 12, 10, 9, 5, 8, 7, 6; 12, 14, 14, 12, 8; 12, 5, 8; 12, 8, 14, 14, 15, 12, 7, 5, 5, 13, 8, 8, 8, 13, 9, 10, 7, 14, 6, 9, 5, 9. Störmer wrote 'The times noted by me can lay no claim to great accuracy, because I was not adequately prepared, but in any case they give a qualitative idea of the phenomenon'. He also remarked that some of these times relate to multiple echoes, but didnot say which.

Only a few changes are required in the sequences as reported in order to construct reasonable star maps from them. It can just as well be argued, of course, that any other changes would make the figures meaningless, so the 11.10.28 afternoon sequence cannot be quoted in support of the above interpretation of the later signals. If that interpretation is correct, however, then the afternoon signals were test transmissions of constellation figures, intended to lead up to the important Boötes figure which was to be completed by us and re-transmitted. (The cessation of Eindhoven signals until the evening meant that it could not be transmitted until then). For example, the first sequence could be a map of the Plough, along with Canes Venacti, α Draconis (Thuban) and Psi Ursae Majoris. It is necessary to assume 2 timing errors, as shown in Fig.4 (a), to get a good agreement with the stars. The displacement of Dubhe and Merak, the Pointers, is in rough agreement with a time interval of 13,000 years – Fig. 4(b) shows the configuration of the Plough 100,000 years ago, according to the *Larousse Encyclopedia of Astronomy*, and the reference line AB, formed by the first and last echoes of the group, points towards Epsilon Boötis.

The 5-dot and 3-dot groups can be identified, again very tentatively, with segments of Draco. The last sequence of dots is least impressive of all, but may represent the strip of sky from Delta and Epsilon Boötis to β Librarum and μ Virginis. Rotation of the star map tracing is again required to obtain a fit in both upper and lower halves of the diagram, but this time the rotation is about the mid-point of the signal, not about anything of astronomical significance. A timing error has to be assumed to include Epsilon Serpentis Capitis (mag. 3); 7 fourth-magnitude stars appear, 6 others do not. However, reference lines again point to Epsilon Boötis and give the limits of rotation of the star chart. Perhaps if the signal had been timed accurately, then the above objections could be overcome.

One last point, fairly striking, can be derived from the 11

and 24 October signals. Considered together, they chart an area of the sky containing Ursa Major, Canes Venacti, Coma Berenices, Boötes, Corona Borealis, Serpens Caput, Hercules, Draco, Lyra, β Librarum, μ Virginis, and possibly some stars from Ursa Minor and Leo. Not having the 24 October sequence in full, we cannot set the exact limits of this area at present; but there seems to be a definite possibility, from Fig. 6, that the frame of reference will be oriented about Epsilon Boötis.

Epsilon Boötis (common names Izar, Pulcherrima) is a double star. Its distance is, incredibly, 103 light-years – presumably a coincidence, since Bracewell's article considered the different implications if intelligent communities in the Galaxy are on average 10, 100 or 1000 light-years apart. The angular separation of the 2 stars is 2."8, so they are about 88.5 Astronomical Units apart, well over 8,200 million miles – quite enough for both stars to have planetary systems. However, both stars appear to have left the Main Sequence. Epsilon A is an orange giant, Type K1, absolute magnitude 0.00. It might be that the departure of the major sun from the the Main Sequence, with a consequent rise in the background radiation during the blue star phase, brought about the appearance of intelligence in the planetary system – perhaps as a mutation which the continuing rise in temperature made advantageous. The rise of man on Earth would have been sufficiently rapid, over the last 2,000,000 years, say, to have achieved space travel before similar changes in our Sun made the entire Solar System uninhabitable. It seems clear, however, that in sending probes to possible habitable systems out to 100 light years, and programming them to seek out habitable worlds and listen for intelligent life, the inhabitants of the Epsilon Boötis system were not making Bracewell's dispassionate attempt, motivated by scientific curiousity, at interstellar communication. They were looking for new homes; probably the space programme was the total commitment of their race, and by 13,000 years later we may suppose that their efforts have met with final success or failure.

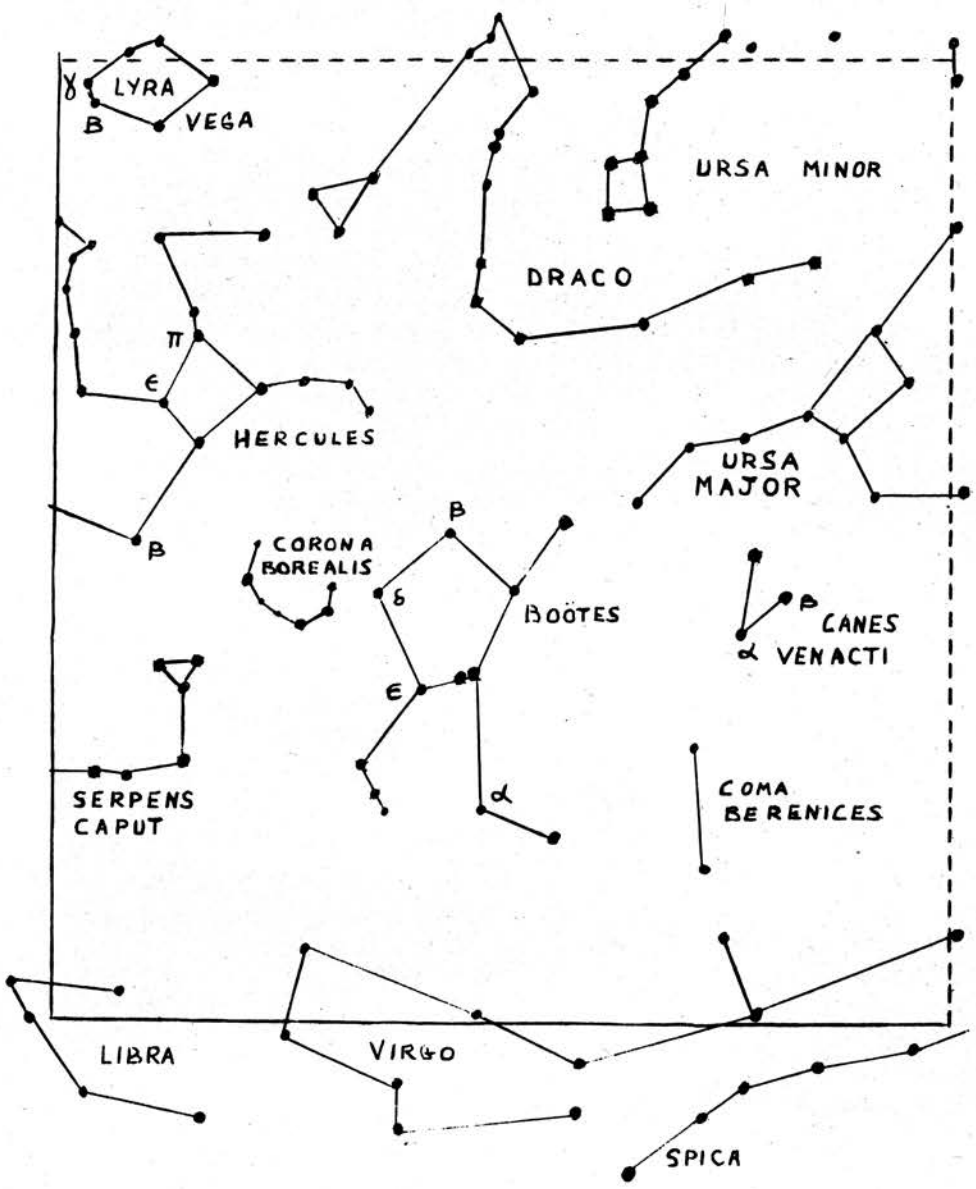


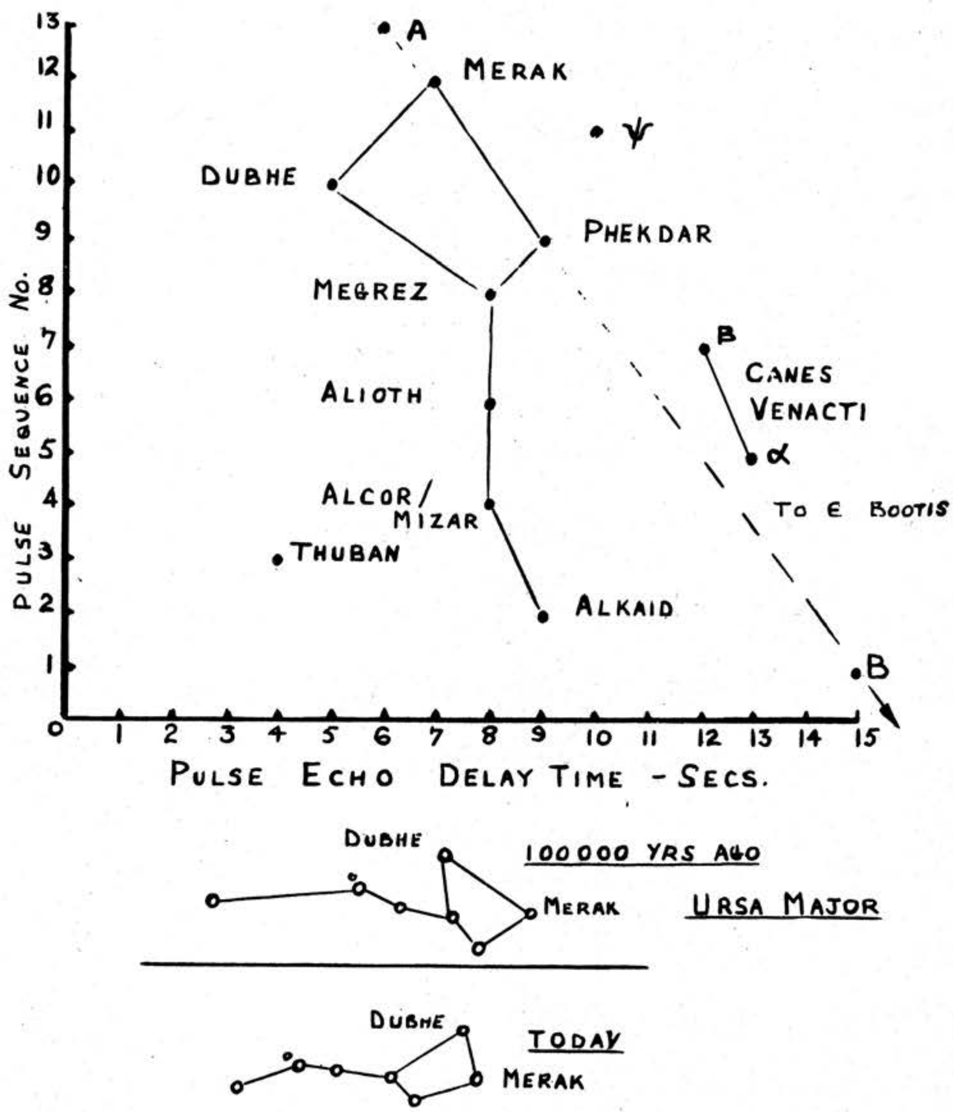
Fig. 4. The Störmer Sequence of 11 Oct. 1928. This is interpreted as a possible map of Ursa Major by assuming that the delay times for echoes 8 and 11 are in reverse order to that reported by Störmer. A and B, the first and last pulses, form a reference vector pointing to Epsilon Boötis.

If space travel and environmental conditions were so important to them, we would expect to find information on their planetary system in the signals at some early stage. That prediction was indeed fulfilled; but first, alas, there is a frustrating gap in the published records. Hals heard echoes again on 14 February 1929, 15.2.29, 18.2.29 and 19.2.29. (N.B. The statement by Strong that echoes were never heard again is not correct).

On 18 February 1929 Andreas Kleve, at the telegraph administration receiving station at Bodö, near the Arctic Circle, heard 5 echoes during a 30-minute transmission from Eindhoven, of 12 or 13 seconds delay, on the 44th, 45th and 60th pulses of the transmission, 'also of the last 30-sec. dash' [9]. Evidently the Eindhoven transmissions had been changed in some way, but no further details were given.

On 19 February 1929, Appleton and Barrow at King's College, London, heard very distinct echoes, of length more than 2 seconds and delays up to 25 seconds, during an Eindhoven transmission lasting one hour. On 20 February 1929 Hals, 'alerted by Eindhoven' heard 2 echoes of 8 and 18 seconds on the 23rd signal of transmissions lasting one hour. Hals heard echoes again on 28 February 1929, 4 April 1929, 9 April 1929, 11 April 1929 and 23 April 1929. Apart from the transmission times in each case, and the 2 fragments quoted above, no further details were published at the time and so far they have proved impossible to trace. Professor Störmer is dead, and his colleagues have no records of his experiments; King's College are unable to trace Barrow, and have no records of his work; and so far Philips at Eindhoven have not been able to help. From 1928, to the present day, scientists of many nationalities have attempted to explain the phenomenon of long-delayed echoes; I have checked 26 references to date, but in every case where echo sequences are quoted, those of 11 October 1928 and the same 21 of 24 October 1928 are quoted as typical. There seems little possibility of bridging the gap between the signals of October

Fig. 5. The approximate area of sky covered by 11 and 24 Oct. 1928 sequences. The boundaries are approximate because the sequence of 24 Oct. is incomplete.



1928, and those heard in May 1929.

In May 1929 a French expedition was in Indo-China to make observations during an eclipse of the Sun. J. B Galle and G. Talon, captain of the naval vessel *'Inconstant'*, had orders to study the effects of the eclipse on radio propagation, especially with respect to long-delayed echoes [10]. Their equipment was a 500-watt short-wave transmitter, with a 20-metre aerial attached to an 8-metre mast, powered by the generators of the Indo-China Hydrographic Service vessel *'La Perouse'*. Two dots were transmitted together every 30 seconds on 25 metres, varied in a fixed musical sequence in order to indentify the echoes. (It was still found that the echo frequency was exactly that of the transmitted signal). The receiving equipment included an oscilloscope display, but the observers found the echoes could be plotted more accurately by ear. Two observers worked together, one listening to a speaker, the other with headphones, to ensure the accuracy of the results, and all the published sequences, over a period of 3 days, were recorded by the same observer.

In their preliminary report [11], Galle and Talon said that echoes ceased altogether for the duration of the eclipse, and some later authors have repeated this statement [12]; more accurately, however, echoes ceased at 13h 51m and began again at 13h 54m 29s. The duration of the eclipse was from 13h 53m 45s to 13h 58m 25s and similar pauses occurred in the echo sequence at other times during the day.

The delay times ranged from 1 second to 30 seconds, though two 31-second echoes and one 32-second echo were heard between 15.40 and 16.00 on the day of the eclipse. The occurrence of 1 and 2-second echoes might seem to disprove the hypothesis of a space probe in the Moon's orbit, but for an extraordinary circumstance. At 14h 19m 29s on the day of the eclipse the operator 'forgot' to send the signal, but echoes came in at 5 seconds and 10 seconds nevertheless. From this Galle concluded that some of the weak echoes might have delays of 40 seconds or longer; reading between the lines, it seems that the weak echoes were too faint for the indentifying musical tones to be distinguished. It is possible, therefore, that the probe had begun to anticipate the signals from Earth and was transmitting 'echoes' before the signals reached it.

The full record of 8, 9 and 10 May was published by Galle in *'L'Onde Electrique'*, Vol. 9, 1930, as a large fold-out supplement. Transcribing it was a massive task, made more difficult by the absence of vertical or horizontal guide-lines. Some guide-lines were supplied on a partial reproduction in the *'Proceedings of the Royal Society of Edinburgh'*, Fig. 7 [13], but the scale was half that of the *'Onde Electrique'* graph in which vertical guide-lines, had they been supplied, would have been 1 mm apart. With practice, however, and repeated checking, I was able to transcribe the echo sequences for the 3 days into the same system I had used for the October 1928 signals.

A detailed account of the 9 May panels is in preparation. Most important, however, is panel 7: Its main figure, the upright rectangle right of centre, is the only feature of the panels to be conspicuous even in the Galle-Talon diagram.

The starting points are clear: at the top of the figure we have a row of 7 dots, and below it a row of 14 divided into 4, 3 and 7, from which the horizontal line to the right leads into the constellation figure of Boötes – the only time that star figures appear in the first 10 panels of 9 May, and clearly added to the upper right of the diagram by the probe in order to complete the figure. From that starting row, the logical sequence of the main figure is so clear that it can be represented in standard, even colloquial English, as follows:

AB – Start here.
BC – Our home is Epsilon Boötis.
CDE – which is a double star.
FG, GH – We live on the 6th planet of 7
CH, GK, JKL – check that, the 6th of 7 –
EM – counting outwards from the sun
FEG, GN – which is the larger of the two.
HO, OP – Our sixth planet has one moon, our fourth planet has 3, our first and third planets each have one.
GQ, QR – Our probe is in the orbit of your Moon.
ST – This updates the position of Arcturus shown in our maps.

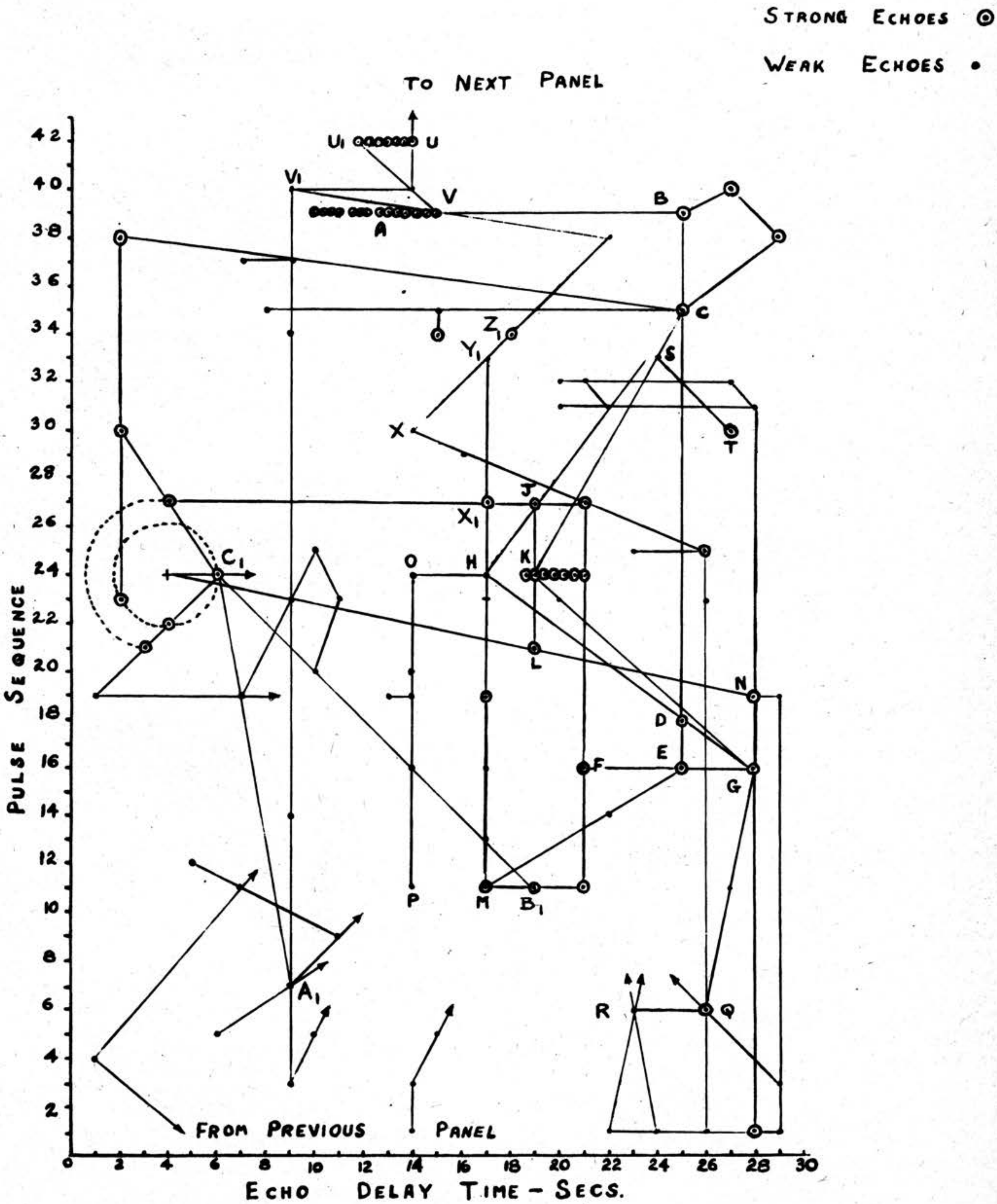
The line ST, with its parallelogram frame drawing attention to it, makes an important point: that since the transmission of the star maps in October 1928, more of the probe's systems had come back on-line. Visual sensors were operating, and a check of the critical star map showed that it was outdated. The error could not be eliminated without redrawing panel 7, but a correction was added to bring the panel up to date. If the panels had been recognised and acknowledged in the 1920's, one wonders what other systems might have proved ready for use.

It seems clear that the main figure of panel 7 is meant to be read from right to left. A lesser 7-dot vertical line appears on the left of the main figure, ending at V1 (the 6th planet's moon is shown), and around the lower part of the panel various lead-in-lines run from left to right, but these add no further information, leading only to the main right-left sequence. The only thing in the main sequence to read from left to right is the starting line, AV. The line U1V connects 7th-planet dots; and the sequences VW, Wx, XY, YZ and X_1Y_1, Y_1Z_1, suggests a connection between the 7th planet and the space probe. This reinforces a tentative interpretation of panel 9, namely that the probe was launched from the 7th planet to maximise the gravitational boost in a swing around the two suns.

The scale of the planetary system is given at extreme left, by the distinctive figure mentioned in connection with panel 4. It seems that the probe makers express planetary distances as we do, using the distance of their planet from the sun as their 'Astronomical Unit', and they give the distance between their 2 suns in terms of that unit so that we can determine its value. Evidently the 2 suns are 7.5 Epsilon Boötis A.U. apart; therefore the E.B.A.U., the orbital distance of the 6th planet, is 1,097,000,000 miles, as accurately as it can be determined from this diagram. The 7th planet, at 1.66 E.B.A.U., is 1,821,000,000 miles from the major sun.

One would like to see some calculations on the stability of such orbits in the Epsilon Boötis system. There was an inference before that both stars were more massive and shorter-lived than the Sun. However, to have a habitable planet at 1,000,000,000 miles during its Main Sequence lifetime Epsilon Boötis would have required a spectral type

Fig. 6. ***(Right)*** **One of several sequences recorded on 9 May 1929 interpreted as a presentation of data concerning the possible Epsilon Boötis planetary system (panel 7 in the sequence). For explanation see text.**


STRONG ECHOES
WEAK ECHOES
TO NEXT PANEL
FROM PREVIOUS PANEL
PULSE SEQUENCE
ECHO DELAY TIME – SECS.
U1 U V1 V A B C Z1 Y1 S X T J X1 O H K C1 L N D E F G P M B1 A1 R Q
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42

close to AO, with a Main Sequence lifetime of 10^9 years or less and, according to modern views on planetary formation, virtually no chance of having planets at all. F5(7) is the spectral type below which stars have the very slow rotation we associate, tentatively, with the formation of planetary systems. In *'Habitable Planets for Man'*, Dole puts the upper limit for system habitability at F2 on the grounds that life must have at least three billion years of Main Sequence sunlight in order to produce an Earth-like atmosphere [14].

For Epsilon Boötis, therefore, there are two possibilities: either the probe's makers were giant planet creatures, quite unlike ourselves – in which case their probe would not have approached Earth seeking a new home for them – or the 6th planet was not the original home of their race. In panel 7 two lines appear, A1C1 and B1C1, leading from the second planet to the sixth. It seems possible that the second planet was the probe makers' original home, and later panels contain strong suggestions to that effect.

Incidentally, the totality of the 9 May eclipse no longer seems a matter of importance. The pause which so impressed the observers was only the natural break between panels 8 and 9, and the probe was well launched on the main figure of panel 9 before the totality of the eclipse ended.

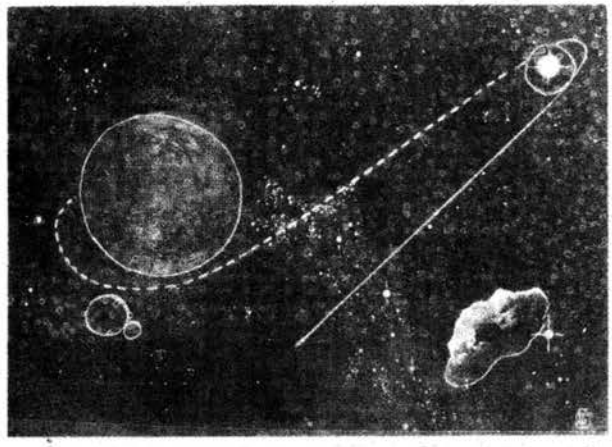
In putting forward the suggested interpretations, it has been impossible to keep using qualifying phrases like 'the hypothetical probe', 'assuming it exists', and 'assuming the patterns are in fact intelligible'. In the long run, only confirmation of the probe's existence could establish that the long-delayed echoes were not a natural phenomenon. However many panels appear to yield meaningful, consistent information, there will always remain a statistical possibility that the dots are randomly distributed and the apparent patterns are illusory. Nothing would be gained, for example,by having other people attempt to solve the same panels from scratch. If 2 people attempt the *Times* crossword and one fails to solve it, that does not prove that the *Times* crossword is a natural phenomenon – and if they both produce the same solution, it suggests but does not prove that that solution is correct. Even less would be gained by submitting the panels to a computer, which could draw all possible lines and all possible curves through the given dots but could not tell which of them were meaningless or trivial. It is quite possible to make nonsense of the panels by drawing lines saying, for example, 'Venus is Mars', but that does not establish that the meaningful interpretations are illusory.

Further Research

There are 18 panels altogether from 9 May 1929, to be solved (I have tentative solutions for 11) and another 12 panels from 10 May which may prove to join up across the 20-minute transmission gaps. (By transmitting 'echoes' of signals from Earth, the probe could at least avoid transmitting when nobody was listening). The 10 panels of 8 May may prove harder to solve, since no distinction between powerful and weak echoes was made in the records. Some of these panels may be 'addressed' to physicists, biologists, etc., rather than to astronomers, and some may defy translation if it is true that the May 1929 signals are the attempt of a society, hundreds of years ahead of our own, to communicate with a culture assumed to be even further ahead. No doubt the interpretation of some panels will remain a source of argument for a very long time.

After May 1929, Störmer stated that no more experiments were carried out for many years. Apparently, however, an extended series of observations was conducted by Appleton and others in 1934; I have not been able to obtain any details of the results as yet. The next attempt to detect long-delayed echoes was apparently that of Budden and Yates in 1947-49, transmitting pulses at 14.5 metres from Ongar in Essex [15]. Results were completely negative, partly, perhaps, because there was far more man-made interference on such wavelengths than there had been in the 1920's and 1930's (see later). In 1967, a search for long-delayed echoes was initiated by the Stanford University Institute for Plasma Research, California. Interference from other pulsed transmitters such as Morse and teletype stations remained a major problem, and no results were obtained until January and February 1970, when 3 echoes were heard.

The Stanford researchers are investigating a hypothesis concerning natural long-delayed echoes, summarised by Crawford, Sears and Bruce as follows [12]. 'An ordinary wave will propagate to height hl, and be reflected back to the receiver (not necessarily at the transmitter site). In the reflection region, some energy will couple into longitudinal plasma waves, e.g. due to slight local inhomogeneities. These waves will propagate along the magnetic field lines, with very low group velocity, and will suffer collisional damping, collisionless (Landau) damping, or both. Now assume that some nonthermal electrons are travelling along the field lines. They will amplify the plasma waves by beam-plasma interaction..... We are discussing a relatively complicated mechanism and assuming rather special conditions. Such an explanation is almost certainly demanded, however. It seems likely that at least 2 conditions must occur simultaneously to render LDE (Long-Delayed Echoes) so rare. If we invoke small scale ionospheric inhomogeneity to transfer energy to longitudinal plasma waves, energetic electrons to amplify them, and a further inhomogeneity to couple out an ordinary wave signal, the resulting wave mechanism is probably



Space probe leaves the Epsilon Boötis system. Launched from the orbit of the seventh planet (hidden behind major sun) it has swung around both suns to get maximum gravitational boost from the system (trail fading near the Milky Way) as it passes the sixth planet under drive. The fourth planet with its three moons is visible left of the sun.

Painting by Gavin Roberts.

no more complicated than that necessary to account for LDE'.

On 22 January 1970, a single echo was heard. 'The transmitted signal for the first consisted of two 100-msec pulses 1.5 sec. apart. After a 15-sec. delay two similar pulses were received. Their frequencies were, respectively, 55 and 60 Hz lower than the original transmission, and the time interval between them was compressed 25% to 1.1 sec. Neither the frequency shift nor compression effects had been reported previously'. On 14 February 1970, two instances of LDE were detected, about 1½ hours apart: '......the delays were about 20 sec, the echo frequencies were about 100 Hz above the transmitted frequency, and the time spacing decreased 35 and 50% respectively'. Since those first results were announced, the Stanford group have accumulated 20 to 30 records which might be long-delayed echoes. No long sequences have been observed, however, and never more than two echoes in one day [16].

It seems to me that the Stanford research cannot settle the question of the probe's existence or non-existence. Long-delayed echoes have been detected at times when ionosphere conditions match those required by the beam-plasma interaction hypothesis, but have not, as yet, formed any long sequences of echoes without frequency shift or compression in time. Even if a 1920's-type sequence were to be received, it might merely indicate that the probe had been re-activated; even if the sequence could not be resolved into meaningful signals it might still have come from the probe, because we shall be very fortunate if everything we receive from it is immediately comprehensible. And equally, absolute confirmation of the probe's existence would not rule out the possibility that beam-plasma interactions can and do generate natural long-delayed echoes.

If the probe exists, however, it is not likely that we can contact it on wavelengths which are now heavily used for terrestrial radio traffic (and the Stanford results may therefore be genuine beam-plasma interactions). Between 1932 and 1969, according to the radio journal *'QST'*, there have been more than 40 convincing reports of long-delayed *speech* echoes on various frequencies [17]. (See Table 1). I have also heard that echoes are occurring as interference on communication satellite wavelengths, but have no details as yet. The persistent, 'unimaginative' use of long-delayed echoes strongly suggest that the 1920's echoes were returned by a machine artifact rather than any kind of 'piloted' spacecraft.

Attempts to contact the probe by radio should therefore be made on wavelengths we normally avoid, such as those set aside for radio astronomy. The chances of successfully contacting the probe would in fact improve if powerful radio telescopes such as Jodrell Bank or Arecibo were used, in order to come nearer to the signal intensity the probe presumably 'expects'.

After its prolonged failure to attract our attention by radio, however, other channels of commmunication might prove more effective now the roles are reversed. We know that the probe's visual sensors and computing facilities were re-activated by May 1929. Over a distance of a quarter of a million miles, the probe could easily communicate by laser. Attempts might therefore be made to contact the spacecraft by laser probing of the leading Moon Equilateral position. A positive radar blip to aim at would be a great help, but if the probe has an open-framework structure it may be a poor radar target. (However, positive radio contact might cause the probe to use radar enhancement techniques for identification). The laser equipment used in the Apollo lunar reflector experiments could be used for the task, and simple pulses, spaceed at 30-second intervals, should be sent in the first instance. The attempts should be made when the Earth is between the probe and the Sun, so that the plasma collector and therefore (we hope) the visual sensors and laser, are pointing towards the Earth. If laser 'echoes' start coming back with varying delays, and especially if they form recognisable star maps, it will be difficult to maintain that they are a natural phenomenon.

REFERENCES

1. R. N. Bracewell, 'Communications from Superior Galactic Communities', *Nature,* **186,** 670 (1960).
2. James Strong, 'Flight to the Stars', Temple Press, London, 1965.
3. A. H. Taylor and L. C. Young,'Studies of High-frequency Radio Wave Propagation' ,*Proceedings of the Institute of Radio Engineers',* **16,** May 1928, 561-578.
4. C. Störmer, *'Comptes Rendus de l'Academie des Science',* Paris, 5.11.28.
5. C. Störmer, *'The Polar Aurora',* Oxford University Press, 1955.
6. B. Van der Pol, *Nature,* **122,** 875 (1928).
7. P. Morrison, 'Interstellar Communication', *Bull. Phil. Soc.,* Washington, **16,** 58 (1962).
8. C. Flammarion, *'Les Etoiles',* Paris, 1882.
9. C. Störmer, 'Kurzwellenechos, die mehrere Sekunden nach dem Hauptsignal eintreffen', *'Naturwissenschaften',* **17,** Heft. 33, 16.8.29, 645.
10. J. B. Galle, 'Observations Relatives a la radio-electricite et a la physique du globe', *'L'Onde Electrique',* **9,** 257-265 (1930).
11. J. B. Galle, G. Talon and M. Ferrie, 'Recherches relatives a la propagation des ondes radio electriques effectuees a l'occasion de l'eclipse du 9 Mai 1929, *'Comptes Randus',* **190,** 48-52, (1930).
12. F. Crawford, D. M. Sears and R. L. Bruce, 'Possible Observations and Mechanism of Very Long Delayed Radio Echoes', *'Journal of Geophysical Research, Space Physics',* **75,** 34, 1.12.1970, 7326-7332.
13. Störmer, 'Proceedings of the Royal Society of Edinburgh', **50,** Part 11, No. 15 (1933).
14. S. H. Dole, *'Habitable Planets for Man',* Blaisdell Publishing Company, New York, 1964.
15. K. G. Budden and G. G. Yates, 'A Search for Radio Echoes of Long Delay', *'Jour. Atmos. Terrest. Phys.,'* **2,** 272-281 (1952).
16. Private Communication dated 7 Sep. 1972 from Prof. F. W. Crawford, Stanford University Institute for Plasma Research, California, USA.
17. O. G. Villard, Jr., C. R. Graf, and J. M. Lomasney, *'QST',* February 1970.

The author and Ed. Buckley and Gavin Roberts, who kindly supplied original paintings for this article, are members of ASTRA (Association in Scotland for Technology and Research in Astronautics).

THE INTERPRETATION OF SIGNALS FROM SPACE

By A. T. Lawton, AMIEE, FRAS, FBIS.

Introduction

This paper surveys aspects of Communication with Extra Terrestrial Intelligence (CETI) – which is a disciplined fusing of Astronomy, Astrophysics, Information and Communication Theory, and Biology.

Systems of Communication, Methods of Encoding and Decoding Information, and an outline plan for a CETI programme in which both professional and amateur radio personnel can co-operate are discussed.

In all cases, the themes will be within our own present knowledge and feasible projection, but it is freely acknowledged that in this forward looking area, the scene could completely change within the next 2 or 3 decades as a result of new ideas or theories relating to information propagation.

Media and Systems of Communication

All Communication systems use the basic concept of methodically changing the energy or matter content of a given area or volume of space/time. The simple methods of adding ink to paper, talking (air energy modulation), or more sophisticated systems (TV, radio, radar), are all embraced by this definition.

When considering CETI, very long distances (light years) in free space are involved, and with our present knowledge we can only consider modulated electro magnetic radiation (EMR) as the only feasible 'carrier' of energy for these distances. I am therefore ruling out ESP and telepathy which (although being investigated) does not have the sound basis established for EMR by Clerk Maxwell in 1873 [1].

Within the next 50 years we will have developed EMR Communication systems to the point where only natural and economic elements will limit the distance. These may be set as:

(a) The quantum noise limits set by free space, our aerials, detectors, and receiving equipment.
(b) The strengths of materials which set the size and areas of the transmitting and receiving systems.
(c) The percentage of the world's energy we are prepared to devote to CETI.
(d) The percentage of the Gross International Product and priorities we are prepared to devote to CETI.

Methods

Using EMR as a basis several methods can be considered for CETI. Some of them may be actively and economically used now; others will be available as our technology improves but may be used by advanced civilisations. These methods are:

(a) Transmission and reception on radio frequencies of 10^9 - 10^{11} Hz (30 cms. to 30 mm wavelength).
(b) Transmission and reception on optical frequencies 30 μ metres (infra red) to 0.3 μ metres (ultra violet)
(c) Investigating anomalous received radio signals in a more detailed manner on the basis of possible intelligent origin.
(d) Modulation of the Sun's emitted spectrum either by chemical 'doping' or laser transmission.
(e) Placing a coded false 'binary Doppler shift' on a star known to be single.

Methods (a), (b), (c) and a form of (d) are well within our capability and form the basis of our discussion.

Transmission and Reception on Radio Frequencies

This was put on a rational basis by Cocconi and Morrison who advocated monitoring signals on wavelengths close to 21 cm. (1420 MHz) [2].

Drake initiated work in Project 'Ozma' and more recently the enthusiasm has revived particularly in Russia where CETI is taken seriously and is discussed regularly [3.4.5]. A definitive CETI programme has now been set out with a brief to examine the 100 nearest stars for signs of CETI signals. At present the largest 'dishes' in Russia are being used. The prospect of eventually using the giant 600 metre 'Ratan' steerable 'ground dish', raises the number of potential candidates to over 1,000.

Of the 100 candidates in the present Russian programme 12 have now been screened out.

A smaller scale programme has been undertaken by the USA where 2 of the most likely and nearest candidates (Tau Ceti and Epsilon Eridani) have been periodically checked during 1971-1972 with negative results. Tau Ceti also has signals periodically transmitted to it by the Arecibo dish in Puerto Rico. It should be noted that Van de Kamp has hinted at astrometric perturbation of both Tau Ceti and Epsilon Eridani, this being due to possible planetary companions. At this stage he is not prepared to report on the orbital elements of the perturbation.

Transmission on frequencies other than 21 cm of neutral hydrogen may be considered as follows:

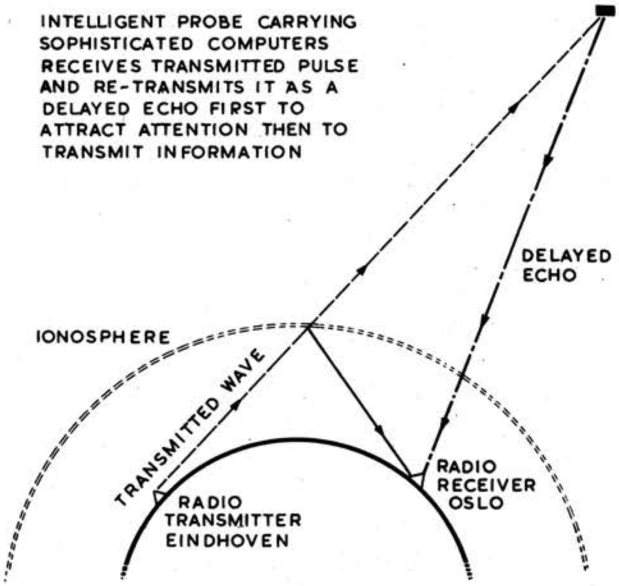
1.8 cm. (16,600 MHz) OH hydroxyl line.
1.25 cm. (24,000 MHz) ammonia line.
0.4 cm. (75,000 MHz) formaldehyde line.

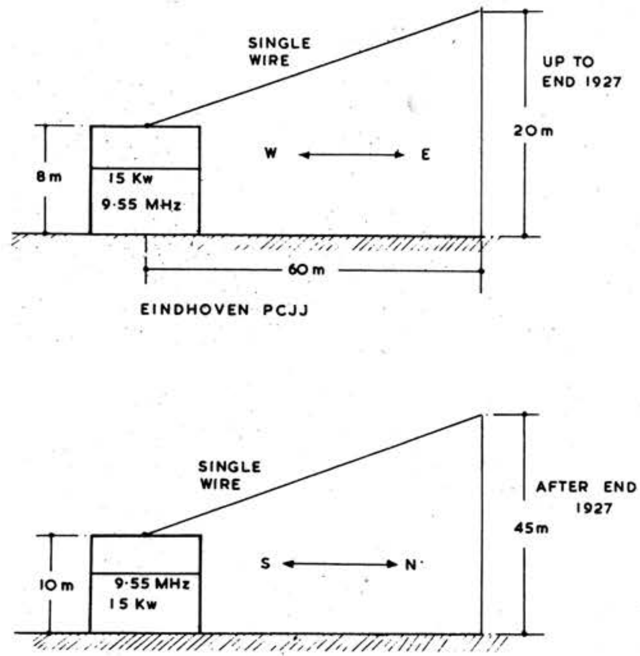
Although it is possible for us to *receive* such frequencies, at our present stage of development we could not *transmit* at the power densities required to achieve interstellar distances. We are just barely able to manufacture high power klystrons and magnetrons working at 1.8 and 1.25 cm., but cannot produce devices functioning at 0.4 cm. We do not yet know how to manufacture masers or plasma systems operating at these power densities, and therefore are at the frontiers of our present technology. However, it fulfills all of the earlier criteria put forward, i.e.,

(a) The Quantum Noise limits are low (especially when operating masers or parametric pre-amplifiers).
(b) Within the 21 cm. band we can produce the power densities required.
(c) Aerials present no difficulty in manufacture (reference the various sizes now in use). A 115 metre fully steerable dish is to be set up in the UK., a 600 metre steerable ground dish is under construction at Ratan, and a 300 metre semi-steerable ground dish exists at Arecibo. It is possible to use aperture synthesis techniques and produce aerials of Square Kilometres collecting area, and very high resolution.

Throughout the world there are approximately, 100 'dish' aerials (or antenna) of 25 metres or more engaged in astronomical or space research alone. This does not include those aerials or dishes used for Defense purposes or for commercial satellite communications.

(d) From these considerations it is plain that the system is economical and viable in terms of little extra invest-





Above, Fig. 1 (a), Intelligent Probe Theory of delayed echo radio signals. The diagram shows the Eindhoven transmitter PCJJ and Störmer's receiver at Oslo 11 Oct. 1928.

Right, Fig. 1 (b), Set up for Störmer/Van der Pol experiments.

ment needed and the power required to operate the equipment for a given 'reach' in light years. The system can be supported by quite modest Gross National Products and does not demand International funding.

So why is it not more fully exploited? Possibly because of credibility, although this is gaining credence and it is to be hoped that within the next few years a properly co-ordinated international CETI plan can be adopted whereby each potential radio telescope receiving system is allocated a specific set of stars to check. Small aerials would examine nearby stars and larger systems stars at greater distances.

Transmission and Reception at Optical Frequencies

This system was first proposed by Townes and Swartz [6] since similar power levels to radio frequencies can now be raised by lasers, particularly at infra red wavelengths where peak powers of 5 megawatts at efficiencies of 25% are achieved with comparatively simple apparatus.

To achieve a given beamwidth requires a very much smaller reflecting mirror than does a radio system, but the mirror must have a high surface finish. Alternatively it is now entirely feasible to borrow aperture synthesis from radio techniques and use a battery of small mirrors each with its own laser for transmission, or photodetector for reception. The system is either 'fired' (for transmission) or 'gated' (for reception) by a central processor in order to achieve the desired wave-front. The sensitivity may be increased by adding extra mirrors as required. The author had earlier suggested the use of Infra Red Interstellar Communications Systems (IRIS) [7, 8] on the premise that another CETI community may have opted for IRIS for economy reasons. Given resolution and/or power per steradian would cost less than a comparable radio system.

A systematic Infra Red Survey might reveal some extremely interesting anomalies, for example stars which were visually single but I.R. binary with one of the I.R. sources pulsating.

A partial small survey of 21 I.R. stars has already been carried out by Murray and Sanduleak [9] with the intriguing possibility that Proxima Centauri is NOT the nearest star beyond the Sun.

Anomalous Radio Signals – Machine Probes

The first known statement concerning anomalous radio signals was made by Tesla [10] but was first treated seriously as signals possibly emanating from an Intelligent Probe in the Solar System by Bracewell [11]. He cited the cases of Long Delayed Echoes (LDE's) which had been reported by Störmer, Professor of Mathematics at Oslo and Van der Pol, head of Radio Telecommunications Research, Philips of Eindhoven. Van der Pol was systematically exploring the propagation characteristics of the ionosphere at 10 MHz – the then so called 'short waves'. A 15 kW transmitter was coupled to an 'L' aerial and pulsed regularly every 20 seconds (Fig. 1). It was calculated that at the expected ionosphere heights, the returned signals would only take a few millisecs. To Van der Pol's astonishment he started receiving pulses delayed by several seconds (Fig. 2).

Co-operating with Störmer in Norway, on 11 October 1928, sequences of signals were received with delays ranging all the way from 3 to 30 sec. [12].

These echoes were always characterised by being clear and free from Doppler shift. Considering the normal state of the ionosphere (shifting layers of particles) this is surprising,

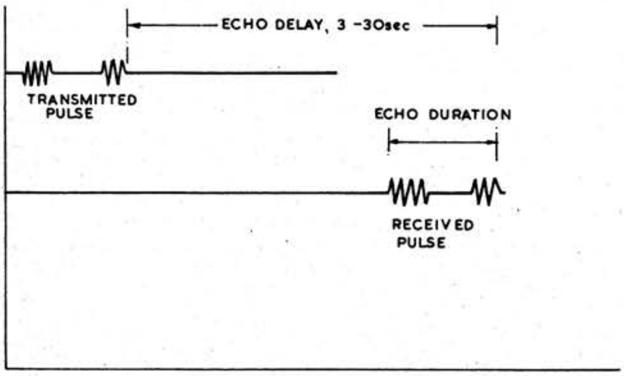


Fig. 2. Delayed echoes received by Van der Pol, Oct. 1928.

but to receive a 3 second echo demands a reflecting body approx. 440,000 km from Earth i.e., a Moon orbit. To receive a clear echo 15 seconds after the transmitted pulse demands a surface at 2.24 million km from Earth. There are other propagation methods which can produce such echoes but they are complex and the exact conditions as yet unknown, but they postulate maser action in the ionosphere, ducted propagation, and multiple round-the-world ionospheric reflection.

Bracewell suggested that the echoes emanated from a probe in the Solar System which was 'sampling' all EMR in the vicinity for traces of intelligence. These echoes are still consistently being reported by amateurs who hear their own call signs repeated after several seconds – and clear of any Doppler shift. The ranges extend from 810 KHz to 144 MHz. There is a long history of 'anomalies in long delayed echoes' reported by radio traffic operators. I have interviewed such personnel – one of whom described it as 'someone calling in a corner of a room'. There is no doubt that the effect is real.

The phenomenon is being investigated by Stanford University but it should be more fully examined, particularly since some of the records of Störmer, Van der Pol and others appear to have been lost or are buried in archives [13].

Further work in the United States has collated the information and concludes that there are two main delay times, namely 2 sec. and 8 sec., (Fig. 3) [14] and a connection with Moon zenith angle. Another characteristic of LDE's is that they are most frequently heard when a new band is starting up.

An important point is Crawford's letter of 7 September 1972, in which he states that Stanford has a total of 20 or 30 records which might be long delayed echoes. However, they have never observed any long sequences, or more than 2 echoes in any one day, and ask Lunan (see pp. 122-131) to keep them up to date.

Modulation of the Star Spectrum

This will not be discussed in this paper.

Decoding and Encoding Signals

Having established a system on a search basis, any possible 'messages' are recorded which is *not* as easy as it sounds. If the system is Beamed Radio EMR, then we should expect a series of pulses (barely discernable from noise, in our present state of development). This will improve as our knowledge of aerials and low noise receivers increases to the theoretical limits.

Before any decoding could be attempted, the records would have to be checked for:

(a) *Coherence,* i.e., correct sequence multiples and not random pulses.
(b) *Elimination of Natural* causes, pulsars etc.
(c) *Elimination of Man-Made* causes, i.e., deliberate fakes or accidental interference caused by harmonics from items on a different wavelength, or cyclic motion of the recording gear.

The possibilities (b) and (c) would be checked by moving the aerial. If the signal is unchanged it is man-made; if the signal changes it is a pulsar or CETI. Since there are now over 60 known pulsars and the hunt still goes on it is quite probable that CETI will arrive by accident and be classed as a pulsar! However, most pulsars seem to radiate their peak radio powers at wide bands around 200 to 800 MHz and we are looking for 1420 MHz narrow band (10-100 Hz) CETI. Therefore a pulsating source should be checked over a very wide frequency range, and any narrow band emission regarded as a candidate.

What form can we expect in the sequences? Drake and others [16, 17] have quoted super prime numbers, e.g., 551 (19 x 29) and 1271 (31 x 41) in strings of 0's and 1's, i.e., 10000101000 etc. When correctly assembled into a rectangle a picturegram emerges, usually a primate with planet symbology.

I personally do not think that these systems are feasible simply because a wrong pulse or worse still, a series of them, destroys the whole sequence and it becomes undecipherable. It is essential to insert a parity check into such a system and once this is done it is possible to transmit whole sequences of pictures [8].

Using this system and a Baud rate of 1 bit per second the following amounts of information could be transmitted in conventional 'Earth times':

1 Hour	3,600 bits
1 day	86,400
1 week	605 x 10^3
1 month	2.6 x 10^6
1 year	28.6 x 10^6

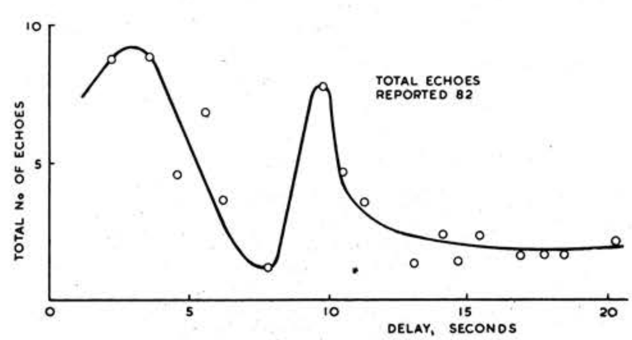


Fig. 3. Delayed echoes collated by researchers at Stanford University, California, which indicate two main delay times, 2 sec. and 8 sec. Delay time versus total number of reported echoes; total echoes reported: 82. (Clark 1971).

Fig. 4. Comparison of Japanese Ideogrammatic and Phonetic symbols with Western (English) Phonetic symbols.

This is an extremely powerful system and is easily machine or man decoded. One merely looks for the evenly spaced repeated 'parity code' and blocks out from then on as a line. If a line is lost its picture content can be guessed merely by placing succeeding lines consecutively. This is simply a combination of computer handshake techniques and TV principles; it is in fact slow-speed digital TV.

Personally, I would opt for picturegrams as the most probable interstellar system. Only if 2 communities have been 'chatting' and 'drawing' for some time will single symbols be attached to multiple drawings. This involves definitions of 'language' for symbols (written characters) are based on 2 fundamental forms of symbolism:

(a) 'Hieroglyphic' languages where the characters are actual drawings of actions, e.g., a boat *with* a sail meant 'I am going *up* the River Nile', and a boat *without* a sail meant 'I am going down the River Nile' in terms of Egyptian heiroglyphics.

(b) 'Phonetic' languages where the symbols are instructions for *sounds* which are attached to objects for description. All modern Western languages use this system.

Japan has evolved a language system which is a mixture of the two forms, i.e.,

Kanji, which is composed of over 3,000 picture/word symbols, and is almost identical to Chinese.

Kana (or Gana), which is an evolved form of Kanji with some 1800 symbols. This is further refined in *Kata Kana* (literally square writing) which uses only 75 symbols. Kata Kana is a truly phonetic language since each symbol means a pronunciation sound e.g. トキ'ヨ means TÖ Kï YÖ, i.e., Tokyo (actually Japanese 'shorthand' takes it down to [illegible]ヨ which *also* means Tokyo), see Fig. 4.

Machine Decoding

(a) *Pictures*

If used for picture processing, then given one or two guiding instructions (algorithms) computers can do the job very swiftly. A simple example would be the instructions to:

1. 'Check that it is a super prime number product and obtain the prime roots'.
2. 'Read out the state groupings (0-1) and plot groups with each one of both prime numbers as x and y axes respectively'.

This would decode a Drake/Oliver picturegram.

A digital TV programme would be more complex but the instructions would be:

1. 'Scan the digits for repeated sequence groups of (say) 3, 4, 5, 6, 7 digits and plot out their occurrence'.

This might give a histogram and a set as in Table 1.

From this we might deduce that the high percentage of regular 7 digit indicates it is the synchronising code and that all subsequent bits are information details.

2. 'Plot out the state groupings with the 7 digit codes as:

(a) On the left. (c) At the top.
(b) On the right. (d) At the bottom.

This is essential for coverage of all possibilities.

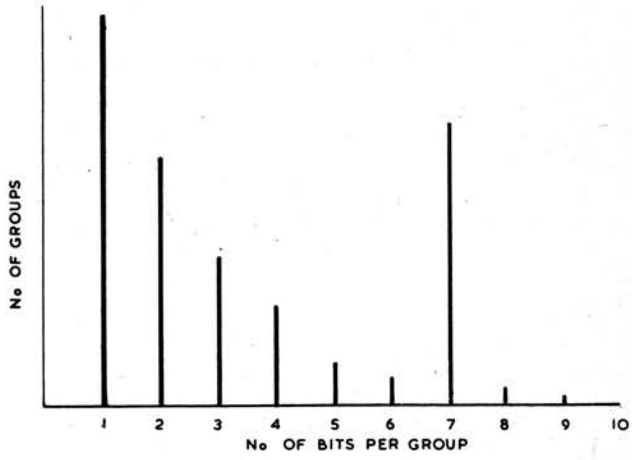


Table 1. Machine decoding: Histogram of Group Occurrences.

(b) *Languages*

Machine decoding and translating of plain languages is much more difficult and final results still demand a human interpreter. I do not intend to cover this subject in detail since it is dealt with in Ref. 4 pp. 133-212 in a rigorous analysis by B. V. Sukhotkin. The methods rely on a knowledge (or intuitive guess) of a similar language to that requiring decoding as to the build up of basic vowels and consonants.

Briefly the system decodes the text into vowels and consonants (established by maximised ratios) and groups these into syllabic texts (again established by weighted ratios).

The final result is a string of characters grouped to give the correct *sounds* in the appropriate language. This then requires final human interpretation to give meaningfulness and correct format (spelling, grammar, etc.).

It is therefore doubtful if CETI for juniors will be a language; we will need to be taught all the required rules for the syntax of Interstellar Esperanto.

Intelligent Probes

CETI from a probe would be very different for most of the work would be done for us. In the limit we would see real time TV pictures for, if Bracewell's hypothesis is correct, an Interstellar Probe with a radiation-hardened intelligent communication system would finally do just that.

However, Lunan [18] has made a more detailed study of the available records of Van der Pol and Störmer [12] who recorded delays of up to 30 sec. Lunan has interpreted specifically some of the delay patterns (those of 11 October 1928 and of 24 October 1928) and they bear a marked resemblance to star charts of the Northern Hemisphere. Furthermore, a demand for an intelligent reply can be inferred from the resultant diagrams. This is in accordance with Bracewell's original words: 'Should we be surprised if the beginning of its message were a TV image of a constellation?' There is also tentative identification of the origin star. If we then directed a large receiving dish toward this star should we be surprised if we received beamed EMR information?

This offloads the problems of technology (noise, power, time, money, etc.) for CETI. The technology load is taken by the probe's designers – and if they can send into our Solar System a device that will have travelled over light years in a radiation-hard environment and decelerated itself into orbit around the Sun (or Earth), then we need not worry about communications problems; they too will have been foreseen and set to match *our* limitations not theirs. The Intelligent Probe method is the *only* way to achieve *specific* direction for CETI talk, for it avoids the semi-randomness of searching (even though the effort is reduced by looking at the 'right types' of star). It is the direct analogy of the helping hand given to a baby just starting to walk. Lunan's work is an interesting example of the deductive logic required for CETI decoding.

This therefore raises the question of an actively co-ordinated CETI plan, with goals and tasks where both professionals and amateurs can participate. The problem falls neatly into 2 areas:

(a) Investigation of specific stars or sky areas for anomalous narrow-band coherent radiation at radio, optical, and visible wavelengths. This is strictly professional work and to a limited degree is already being done. It could be expanded bearing in mind the more than 100 capable systems world wide.

(b) Investigation on a planned 'sound and echo' basis of the phenomena of Störmer and Van der Pol's original work. If possible a hitherto unused or little used frequency should be employed.

Pulsed transmissions could be directed at the leading and lagging Trojan Lagrangean sectors of the Moon's orbit (i.e., 60° ahead and astern of the Moon). Also the semi-stable Earth Lagrangean areas should be checked since they could cause 8 second delays.

The transmissions should be pulsed at intervals of 20 seconds or more and each pulse need only be a few millisecs, and preferably tonally modulated: 1 to 2 KHz would be aurally convenient. The modulation should also be sophisticated not plain amplitude modulation.

The power density into the beam should be higher than used at Eindhoven and 10 KW to 100 KW (dependent on dish size) should produce an adequate signal.

Any convenient wavelength between (say) 10 cm. to 10 m. could be used since the assumed probe would match frequencies. If the phenomenon is natural then this range would provide useful data.

Only one transmitting 'dish' is needed at any time, and the required power is nowhere near that required for Beamed EMR CETI. There is already a well established world wide network of receiving stations.

A series of pulses spaced at say 20 or 30 second intervals and directed at appropriate quarters should establish the validity of received echoes. Of course, there will be hoaxes and fakes – but most amateur returns would be genuine. In any case in a world-wide network, all receiving delayed echoes from a single transmitter, would soon identify the hoaxers.

This programme would probably identify several types of delayed echo, natural as well as those of possible artificial origin.

Further investigations should include:

1. A detailed search of the archives of Eindhoven and Oslo to find especially the lost records of 24 October 1928. Van der Pol quoted receiving 48 echoes, but *ALL* known publications give only 21. Since Lunan tentatively interprets this sequence as part of Hercules, and Corona Borealis and then goes on to forecast that the 25th of the 48 echoes would be Epsilon Boötis, finding and plotting the records would be an important test of the hypothesis. Further long sequence records of 14.2.29, 15.2.29, 18.2.29, and 19.2.29 have been lost.
2. 'Skylab' experiments include photographing the Lagrangean areas. The plates should be examined for unusual objects.
3. An unmanned satellite sent to photograph and inspect assigned areas in greater detail.
4. Finally, one of the 'Skylab' Apollo Command Module's fully manned to be sent to the assigned area. This is possible, since although the orbit is the same as that of the Moon, no Landing Vehicle is required.

To find and identify a probe would provide knowledge unbounded. Apart from what was programmed into by its designers, we would feel impelled to investigate it and if possible to see it, touch it, etc. – assuming it allowed such interference – but this is where concepts of 'Owner Rights' and 'Space Law' emerge [19, 20].

REFERENCES

1. James Clerk Maxwell, *'Treatise on Electricity and Magnetism'*, 1873.
2. Cocconi and Morrison, *Nature*, **184**, 19 Sep. 1959, pp. 844-846.
3. G. M. Tovmasyan, *'Extra-Terrestrial Civilisations – 1'*, Russian edition, 1965, *Akadamiya Nauk Armyanskoi*, USSR, English edition, 1967, Keter Publishers.
4. S. A. Kaplan, *'Extra-Terrestrial Civilisations – 2'*, Russian edition, 1969 *Glavnaya Redaktsiya Fiziko – Matematicheskoi Literatury, Moskva*, English edition, 1971, Keter Publishers.
5. Proceedings of Soviet-American Conference on CETI Sep. 1971, at *Akadamiya Nauk Armyanskoi.* (Armenian Academy of Sciences Byurakon). Proceedings yet to be published.
6. Townes and Swartz, *Nature*, **190**, (15 Apl. 1960), pp. 205-208.
7. A. T. Lawton, *Spaceflight*, pp. 83-85 March 1971.
8. A. T. Lawton, *Spaceflight*, pp. 241-244 July 1971.
9. Murray and Sanduleak, *Observatory*, **92**, Aug. 1972, pp. 112-113.
10. Tesla, Nikola, quoted by L. I. Anderson, 'Extra Terrestrial Radio Transmissions' in letter to *Nature*, **190**, (2 Apl. 1961), p. 374.
11. Bracewell, *Nature*, **186**, (18 May 1960), pp. 670-671.
12. C. Störmer, *Nature*, **122**, (Dec. 1928) p. 681. Van der Pol, *Nature*, **122**, pp. 878-879.
13. D. Lunan, – Private Communication.
14. C. R. Clark, *'QST'* Nov. 1971, pp. 40-45.
15. Crawford – Lunan, Communication, (7 Oct. 1972).
16. F. D. Drake, *IEE Transactions on Aerospace and Navigational Electronics*, Issues Sep. 62, Dec. 62, Mar. 63.
17. B. M. Oliver, *'Interstellar Communication'*, Ed. Cameron, Benjomin N.Y. 1963.
18. D. Lunan, Private Communication.
19. G. V. Foster, *Spaceflight*, Dec. 1972, pp. 477-453.
20. C. E. S. Horsford, 'A British Code of Space Law', *Spaceflight*, Feb. 1963.

CETI QUESTIONNAIRE*

In preparation for the CETI-71 Conference held in Soviet Armenia in August 1971, the Organising Committee sent out a questionnaire to a number of prominent scientists.

These are the replies from Soviet specialists.

1. *What do you understand by an extraterrestrial civilization?*

L. M. Gindilis: A complex, highly organised system, capable of purposeful action, capable of being aware of the outside world and of itself, i.e., of abstract thinking.

S. A. Kaplan: Any state of matter capable of sending sensible information beyond its own System.

V. G. Kurt: A society of reasoning beings which has achieved some technical skill/equipment (means of locomotion, means of storing and transmitting information).

I. A. Novikov: A complex organisation (a 'machine' in the cybernetics scene), actively conscious of its surroundings, capable of forming abstractions, equivalent to or more complex than abstractions of man's second signal system.

I. S. Shklovskiy: Similar to terrestrial civilization but not necessarily anthropomorphic but completely different stage of technological and scientific development.

F. A. Tsitsin: An entity of interacting subjects, interested in other similar communities.

2. *Is there a civilization outside Earth?*

E. A. Dibay: Our civilization is not unique, but I think that there are few others.

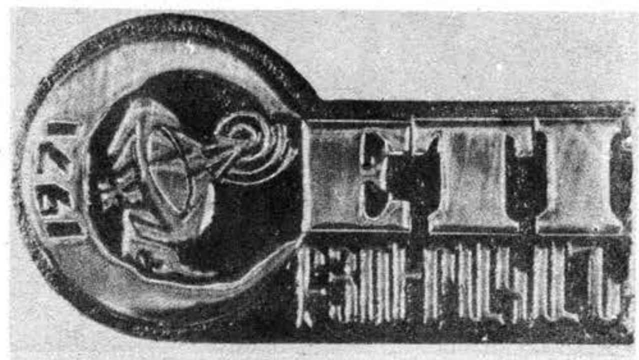
L. M. Cindilis: It is a hypothesis, but to me a very probable hypothesis. Our civilization is, I think, not unique, but possibly a rare phenomenon.

W. L. Ginzburg: I see no reason for doubting the possibility of the existence of other civilizations, but it may transpire that there is no other civilization in the Galaxy.

N. S. Kardashev: I think there are many civilizations in the Universe.

S. B. Pikel'ner: I think that ours is not the only civilization in the Galaxy, particularly if it is true that basic organic compounds already exist in interplanetary dust.

I. S. Shklovskiy: I consider it quite possible that ours is the only civilization in the observable part of the Universe.



CETI 1971 Conference Badge.

3. *Do you consider contact with extraterrestrial civilizations possible?*

V. A. Ambarisumyan: I see no reason which could prevent such contact.

S. A. Kaplan: I consider it quite possible; I cannot see any physical, technical or semantic problems.

N. S. Kardashev: There are no limitations to contact. Initially one should concentrate on the use of electromagnetic waves.

N. T. Petrovich: I consider contact quite possible, because the laws of physics are the same throughout the Universe, and so are the laws of development of living matter.

I. S. Shklovskiy: I consider contact possible, but much more complex than people imagine now.

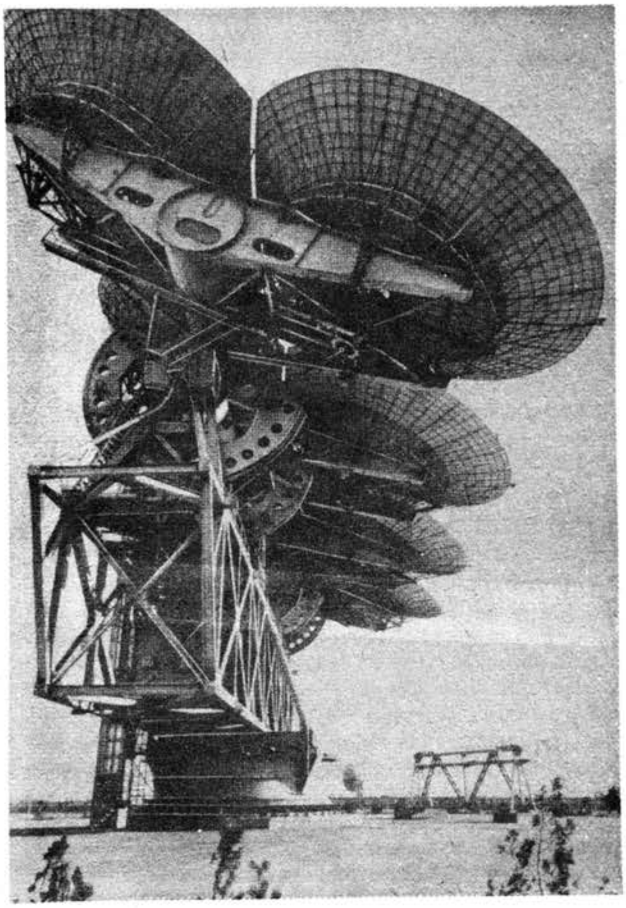
V. S. Troitskiy: Contact is possible, most likely by electromagnetic waves.

* *Summary translation from 'Zemlya I Vselennays' 1972.*

4. *Is it possible, in principle, to understand the information contained in extraterrestrial signals?*
V. A. Ambarisumyan: In principle it should be possible to convey logical and mathematical relations between objects, but difficulties in interpretation may arise.
E. A. Dibay: I consider that history has proved that science can decypher any information.
B. N. Panovkin: It is in principle impossible to separate out the informative content transmitted by signals of other systems.
S. B. Pikel'ner: Interpretation of signals is probably very complex, but in principle it should be possible at some level.
B. V. Sukhotin: Divergence of concepts can be difficult only in short messages, but not in general concepts; therefore one should be optimistic about interpreting extraterrestrial signals.

5. *What methods are required for the search of extraterrestrial signals. Would ordinary astronomical and radioastronomical observations be enough?*
V. A. Ambarisumyan: A search is not worth while until we are able to predict the nature of the signals. If there are reasonable theoretical ideas, one could and should risk a search. An extension of radioastronomical observations of natural signals may lead to an accidental discovery of artificial signals.
V. L. Ginzburg: A large-scale international effort should be mounted for this search, in such a way that even if no such signals are discovered radioastronomical science would benefit from the establishment of huge unique radio telescopes.
N. T. Petrovich: Some extension of existing radioastronomical facilities, used continuously over long periods should be able to cope with the search programme. The optimum range of waves under the atmospheric thickness are apparently 3 - 30 cm.
S. B. Pikel'ner: The probability of finding such signals is low.
V. S. Troitskiy: Ordinary radioastronomical processes, methods and equipment are inadequate for this purpose. Special equipment and a special observation programme should be used.

6. *In what directions should the study of extraterrestrial civilisations go?*
L. M. Gindilis: Continuous radio service at three equi-distant equatorial stations with fixed aerials of low directional nature with equipment for amplitude, frequency and phase analysis.
Continuous search by large aerials of 100-1000 suitable stars, also the Andromeda nebula and neighbouring galaxies. Search of signals in Lagrange libration points.
N. S. Kardashev: Define the optimum range of waves for signals. Create a network for continuous monitoring for signals in the millimetre, centimetre and decimetre range. Study of radio- and X-ray emissions of a hundred Sun-like stars.
N. I. Petrovich: Simulate on 2 computers the contact between two civilizations linked by interstellar-type medium, and study what signals make sense. Or, build ultra wide band (tens to hundreds of Ghz) receivers, as extraterrestrial inhabitants may use ultra short pulses.
A. D. Sakharov: We must develop our equipment and our knowledge further; we may not have reached the state of knowledge, e.g. in the nature of emissions, that another civilization may expect. We must increase the sensitivity (and cost) of instruments and expand methods. The projects for sending signals out are also important; some have reached practical levels.
V. S. Troitskiy: If we want to search for signals we have to study the radio emissions of the nearest stars up to 1000 light years. If we think of the general problem, we have to consider the length of life of a technically developed civilization.
I. S. Shklovskiy: A serious theoretical analysis of the problem in its philosophical, biological, futurological and other aspects is imperative. Secondly, we have to develop special equipment and an observation programme. The problem of decyphering any signals is another difficulty.



Soviet deep space communications antennae at Yevpatoria in the Crimea.

Novosti Press Agency

7. *What are the possible consequences of contact?*
V. A. Ambarisumyan: It would not start with a shock, but in the far future such contact would have a tremendous effect on human society.
V. L. Ginzburg: Possibly harmful effects seem to me too fantastic; any other effects would depend on distance, i.e. travel time of signals.

TERRESTRIAL BIOCHEMISTRY IN PERSPECTIVE: SOME OTHER POSSIBILITIES

By Dr. P. M. Molton*

Introduction

In previous articles the prospect of life similar to our own existing within the Solar System and its origin on the Earth were considered [1-3]. The viewpoint taken was myopic, the conclusion pessimistic. In this article a more optimistic viewpoint will be taken.

Life may be defined as a system capable of maintaining itself and its functions against the disorganising force of entropy, requiring energy to do so. As such, a living system is capable of self-repair.It is also capable of development or evolution. Textbooks give other criteria, such as the ability to reproduce, grow, digest, etc. These functions pertain strictly to terrestrial life only, since we have no evidence that they are essential to life in general.

The major assumption made is that life will evolve anywhere to fit the existing conditions, and thereafter will evolve to adapt itself to changes in these conditions. This is true of terrestrial life, where life originated in a methane-ammonia system, and gradually adapted to an oxygen-nitrogen system. It should also be true of life generally.

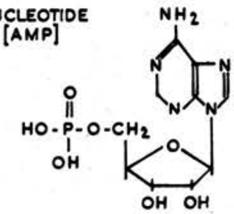
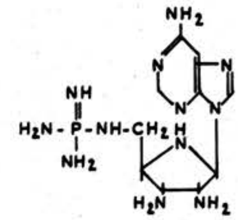
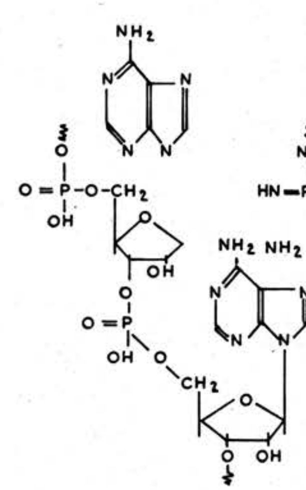
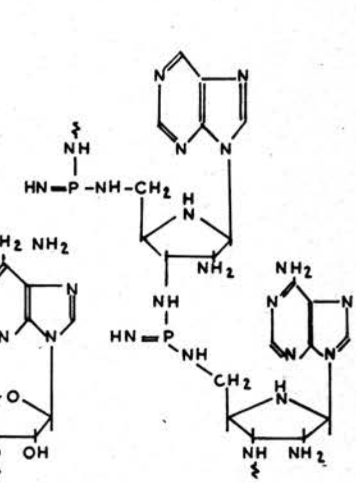
Life also needs a system of carrying information about itself, and of translating this information into chemical structures. Terrestrial life uses nucleic acids for the first, and mainly proteins for the second, although other molecules play an important part. The information storage is necessary, because if it were absent the life form would 'forget' and would mutate rapidly into a non-viable state (this is a consequence of probability, assuming that there are more non-viable than viable states).

Note that these definitions make no restrictions on the elements involved. Carbon may turn out to be the only element from which a life form can be generated, but this is not assumed. Oxygen may be the only gas used for oxidation, but chlorine is not excluded.

The most commonly suggested form of life different to our own is the so-called 'liquid ammonia life' [4]. The theory for this has been worked out in more detail than for any other case. To derive the equivalent of any terrestrial biochemical in this system, simply substitute oxygen by nitrogen, adding hydrogen where necessary to preserve the valency of nitrogen (3 instead of 2). Sulphur can either remain or be replaced similarly by nitrogen. Phosphate groups have the oxygen replaced also by nitrogen, but the element phosphorus remains. Instead of water (H_2O) as the universal solvent we would have ammonia (NH_3). Hence the origin of the term 'liquid-ammonia life'. Table 1 lists a few of these derivatives of common biochemicals, together with their terrestrial equivalents [5]. Of course, not everyone agrees on the possibility that our use of water in our cells is not unique......................Wald [6] states: 'I cannot imagine life existing at all apart from water, or going very far without oxygen', and Horne [7] gives some questionable arguments against non-aqueous biosystems in general.

There are a couple of fallacies that have survived in the literature concerning life based on ammonia, and it is as well to put them to rest before proceeding further. The first is that this is a 'low-temperature' life form, because 'liquid ammonia boils at -33°C'. The second, related, fallacy is that this form of life is impossible anyway, because liquid ammonia freezes at -77°C, and 'this liquid range is too low

TABLE 1. Comparison of biochemicals in terrestrial and ammonia-based life-forms.

Biochemical type	Terrestrial form	Ammonia-based form
FATTY ACID	R-CH$_2$-C(=O)-OH	R-CH-C(=NH)-NH$_2$
AMINO ACID	R-CH(H$_2$N)-C(=O)-OH	R-CH(H$_2$N)-C(=NH)-NH
NUCLEOTIDE [AMP]		
GLYCERIDE [FAT]	CH$_2$-O-C(=O)-[CH$_2$]$_n$-CH$_3$ CH-O-C(=O)-[CH$_2$]$_n$-CH$_3$ CH$_2$-O-C(=O)-[CH$_2$]$_n$-CH$_3$	CH$_2$-NH-C(=NH)-[CH$_2$]$_n$-CH$_3$ CH-NH-C(=NH)-[CH$_2$]$_n$-CH$_3$ CH$_2$-NH-C(=NH)-[CH$_2$]$_n$-CH$_3$
PROTEIN	-[CH(R)-C(=O)-NH]$_n$-	-[CH(R)-C(=NH)-NH]$_n$-
		

* *Laboratory of Chemical Evolution, Dept of Chemistry, University of Maryland, College Park, Md. 20742, U.S.A.*

for the existence of life'. Both of these arise from the same cause, which is that ammonia has these properties at 1 atmosphere pressure and at 0°C. If the pressure is increased, the boiling point is raised and the freezing point is lowered (to a lesser degree). At 60 atm. pressure, the boiling point is 98.3°C, giving liquid ammonia a liquid range of 131°C. We could not tolerate 98.3°C for long, and water has a liquid range of only 100°C under our normal conditions! Hence liquid ammonia life is not ruled out, and it is not necessarily a low-temperature form. As for the idea that a large liquid range is desirable for life, this is only true if the environmental temperature is variable – 1°C would be perfectly adequate if the temperature never varied.

The third fallacy is that 'enzymes will have no activity in liquid ammonia because the pH is much too high' (alkaline). pH is a measure of acidity, and ammonia (in water) is strongly alkaline. Enzymes do not have high activity in strong aqueous ammonia, it is true, but this is not the case in point. In a completely anhydrous ammonia system, the pH scale would be that for ammonia, not water. By a fortunate chance, biochemicals derived for the ammonia system as described above bear the same relation to the ammonia scale as terrestrial biochemicals do for the aqueous scale. This is difficult to put over in a few words, but an example will suffice! Bicarbonate in water has a dissociation constant (pK_a) of 6.1, and the neutral point of water is at 7.0 pH units. Guanidine has a value of 13.6, is the ammonia 'equivalent' of carbonate, and fits just below the ammonia neutral point of 15. Hence, in both systems, the equivalent chemicals are weak acids. In ammonia, ammonium chloride is a strong acid!

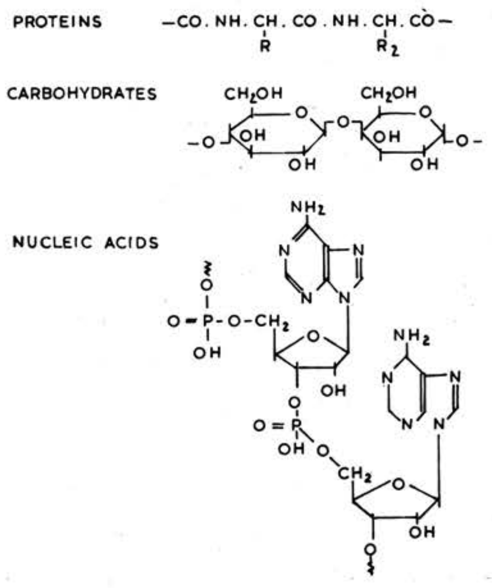
We tend to get carried away by the similarities between the ammonia and water systems, and to forget the differences. One major difference lies in the inorganic chemistry: Metal salts in water tend to be aquated, and in ammonia, ammoniated. For instance, ferric chloride in water has the formula $[Fe(H_2O)_6]^{3+}3Cl^-$. In ammonia it may be $[Fe(NH_3)_6]^{3+}3Cl^-$ – but this is not essential. Ammonia and water are not *identical* chemically, and there are many instances where the water and ammonia derivatives are not the same. Certainly, such things as solubilities are different. An ammonia-based animal would probably use caesium and rubidium chlorides to regulate the cell membrane potential, since these are soluble in liquid ammonia and the normal sodium and potassium chlorides are much less soluble.

The conclusion from all this is that life based on ammonia instead of water is certainly possible, theoretically, at the superficial level. If we delve further into the complex biochemistry of the cell, we could find some insuperable barrier to ammonia-based life – but it is hard to conceive of any obstacle so insuperable that it would rule it out altogether.

Silicon-life

No discussion of extraterrestrial life forms is complete without some attempt at 'silicon-life'. This has made such an impression on the human imagination that it is the form that immediately comes to mind whenever life 'not as we know it' is mentioned. In a way this is a pity, since it is by no means the most likely form of life on theoretical grounds. However, is it possible? Horne [7] gives a formula for the probability of silicon life, based on the relative numbers of *known* silicon and *known* carbon compounds. Obviously, this is a fallacious argument, since the only reason that a particular compounds is known may be that someone has taken the trouble to look for it. Another common argument against silicon life is the idea of catenation, and this requires a small digression before it can be dealt with.

Carbon compounds frequently contain long chains of carbon atoms linked to each other. This ability of an atom of an element to form stable bonds with other atoms of the same element is called catenation. It is often given as the reason why our life form is based on carbon, since no other element possesses it to the same degree. Silicon can form stable compounds with hydrogen, containing up to about 6 silicon atoms, but no more. Hence, silicon cannot form the basis for life – or can it? If we take the trouble to look at the common polymer types on which terrestrial life is based, we find the following:



There are others, but the backbones of the major types above *contain no more than two consecutive carbon atoms.* Although the side chains contain up to about eight carbon-carbon bonds, and certain vitamins and trace components of the cell contain units of up to 40 C-C bonds, we are concerned only with the backbone: Catenation is not a necessary requirement for the production of terrestrial polymer chains. It may not even be necessary in the side chains – this has never been proven.

The requirement then becomes one of the ability to form stable polymers, and silicon is certainly able to do that. The rocks of the Earth are composed of silicon-oxygen polymers to a very great extent. The silicon-oxygen bond is very stable – more so than the C-C bond on which our life is based, the figures being 144 Kcal/mole for C-C, and 176 for Si-O. Even the Si-Si bond is not so very weak, being roughly half this strength [8]. Why, then, does the Earth not support silicon-based, rather than carbon-based life?

The answer lies with the fact that the Earth has a plentiful supply of water, and in the presence of water any silicon compound of any degree of complexity is hydrolyzed to silicon dioxide (or the hydrate, silicon acid). Hence, water cannot be used as a solvent to support a silicon life form. For the same reason, neither can ammonia. The atomic structure of silicon renders it susceptible to polar solvents, so that its compounds are not stable. This is the only reason, since silicon can form compounds with rings, chains, and

other forms like those with which terrestrial biochemistry is favoured, particularly if oxygen and nitrogen are incorporated into the structures.

If only non-polar solvents are suitable, then the most likely ones would themselves be based on silicon. On silicon-rich and oxygen-poor planets, silane (SiH_4) would serve at low temperatures or high temperatures. Alternatively, silicon tetrachloride or tetrafluoride could serve. The only chemical requirement is that of the absence of water and ammonia, or other polar solvents. Given this, silicon-based life is theoretically possible. However, it is difficult to conceive of a way in which it could have evolved from simple inorganic materials. This may be due to our own ignorance of silicon chemistry as much as to any inherent theoretical difficulty.

It seems, therefore, that if we are to investigate silicon-based life, a suitable place in which to do it would be the laboratory, since we need much more data on silicon chemistry. In particular, silicon chemistry in non-polar solvents, and at high and low temperatures and pressures. Earth-like conditions obviously do not favour silicon life!

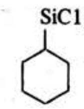
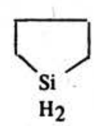
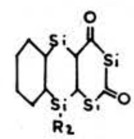
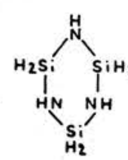
There is a half-way system suggested by Pimentel *et al* [9] which makes use of silicones. This has some of the advantages of carbon chemistry since it includes normal organic molecules as side chains attached to Si-O-Si or Si-N-Si polymer backbones. It is basically a hybrid system, but has one basic disadvantage – on any world where chemical evolution had progressed far enough to generate relatively complex carbon compounds for side chains, then it is highly likely that polymers of these compounds would form, rather than that they would form a hybrid with a completly different form containing silicon.

Some of the more interesting silicon compounds and silicones, from an exobiological point of view, are listed in Table 2. However, unless we make it ourselves, the evidence at present is against the existence of any form of silicon-based life.

Halogen Life

Yet another system, somewhat bizzare at first sight but with a great deal in its support, is the carbon-halogen group. In this, hydrogen is replaced partly or wholly by chlorine or fluorine. Bromine and iodine are excluded because their atoms are so large that they greatly restricted the number of available compounds, and because their abundances in the Universe are low. Concerning abundance, it seems that certain stars are deficient in oxygen to the extent that chlorine and fluorine may actually exceed this element in concentration, so that there is some hope that halogen-rich planets may exist. If this is the case, we could have water oceans and an atmosphere rich in chlorine or fluorine. In some cases, where the hydrogen concentration was initially higher, the oceans would be of hydrochloric or hydrofluoric acid. Here, respiration would consist of the conversion of organohalogen compounds to carbon tetrahalide and the appropriate hydrogen halide; photosynthesis would photolyze the carbon tetrahalide to organohalogen compounds and free halogen gas. Of the two likely halogens, chlorine is the most likely to form a living system, since fluorine is so chemically active that it reacts even with water, to form fluorine monoxide, F_2O. Chlorine reacts much more slowly, and this complication is avoided. There is nothing theoretically wrong with this system. In fact it could have advantages over our own, since the reduction of carbon dioxide in terrestrial photosynthesis is somewhat more difficult than the analogous reduction of carbon tetrachloride.

TABLE 2. Organosilicon compounds of interest relative to a possible life form based on Si or Si-C structures.

Compound	Structure	
Perchloropentacosa-silane	$Si_{25}Cl_{52}$	Prepared from $SiCl_4+H_2$ $\xrightarrow[1000\,^{\circ}C]{Quartz}$ Demonstrates stability of Si-Si bond.
Methylsilanes	$(CH_3)_nSiH_{(4-n)}$	Produced by sparking through $Si + H_2 + CH_4$, with BCl_3 catalyst.
Cyclohexyltrichloro-silane		Produced by sparking through $SiCl_4 + C_6H_{12}$. Analogous experiment to primitive Earth-type synthesis.
Silylamine	SiH_3NH_2	One of many Si-amines. Carbon analogues are important in terrestrial life.
Silacyclopentane		Stable at 500°C over platinum – demonstrates stability of Si compounds.
		Silicon-containing heterocycle similar to flavin structure in vitamin B.
Cyclotrisilazane		Could replace aromatic and heterocyclic rings in terrestrial biochemistry; Also could be used as a polymer base.

In Table 3 are listed some of the chlorine-based analogues of our terrestrial chemicals.

Looking more or less at random through the theoretically possible life systems is all very well, but it is somewhat disorganized. We have looked at some of the very simplest chemistry of some of these systems. In the case of the liquid ammonia system, one or two of the differences between this and the terrestrial chemistries were mentioned. There are others. The actual shape, or stereochemistry, of the molecules plays a vital part in the chemistry of living processes. The stereochemistry will be different for every system, since the atoms comprising it will not be the same.

Because of this, analogous chemicals in two systems may have different solubilities, structures, and formulae. We have considered the basic chemistry related to the structure of the systems, but have not even mentioned the complex chemistry required for energy control, reproduction and repair, etc. If we represent the terrestrial system of life as being based on the reduction of carbon dioxide by Sunlight, and the oxidation of organic materials to carbon dioxide by animals, then we have a crude representation indeed. We can do a similar thing for the other proposed biochemistries (this is done in Table 4) but the results are the merest guideline. If we are ever to get any further with the exploration of non-terrestrial biochemistries, it is necessary to start from the beginning and develop some sort of system. With this in mind, it is instructive to perform an exercise into just which chemical systems are capable, *in theory*, of leading to a living system. Our basic requirements are that these matrices must be able to generate a large number of variants (to provide the chemical complexity needed to maintain structure and function), be stable under stated conditions (to avoid mutation out of existence), and be as simple as possible (so that we can understand them!). Ideally, the basic matrix should contain just 2 elements, but the first criterion of variability cannot be satisfied with this; the variants would be chemically similar and could not fulfil the required number of functions. If three elements are used, a number of possibilities arise. Life based on carbon, hydrogen and oxygen, for instance, or on carbon, hydrogen, and nitrogen. We ourselves contain C, H, N, O, P, S, Cl and a few metals. If we strip away all but the main elements, we conclude that we are somewhat between a C-H-O and a C-H-N system. The pure C-H-N system is the liquid ammonia life described earlier. We can list the combinations of elements that would satisfy the conditions given above, and resistrict them somewhat by applying other considerations, such as universal abundance, atomic size, etc. Doing this, the list obtained is:

CHO	CHS	CFO	CFS	CClO	CClS
CHN	CHP	CFN	CFP	CClN	CClP

This gives us twelve classes of system, with an almost infinite degree of mixing possible between them. To make the principle clearer, if we take the common chemical, glycolic acid, and write the various changes that take place in it as we pass from one system to another, we get:

$HO{-}CH_2{-}C({=}O){-}OH$	$H_2N{-}CH_2{-}C({=}O){-}OH$	$H_2N{-}CH_2{-}C({=}NH){-}NH_2$	$HS{-}CH_2{-}C({=}O){-}SH$	$HS{-}CH_2{-}C({=}S){-}SH$
C–H–O	C–H–O–N	C–H–N	C–H–O–S	C–H–S
Glycolic	Glycine	Glycinamidine	Thioethylthioic acid	Thioethylthionthioic acid

Other variants are possible, but this gives an example of three 'pure' (3-element) and two mixed systems. The C–H–O–N system is our own. If, however, we extend this sort of direct substitution to other systems. for instance the C–H–P and C–F–N, then we would obtain:

$$H_2P{-}CH_2{-}C({=}PH){-}PH_2 \quad \text{and} \quad F_2N{-}CF_2{-}C({=}NF){-}NF_2,$$

respectively. There is no reason to expect these particular compounds to be stable, although at low temperatures they could be. This illustrates the danger of replying too heavily on substitution, and not enough on the known chemical properties of the elements concerned; it should be perfectly possible, by making full use of the known properties of phosphorus and fluorine, to obtain much more stable intermediates than these. Also, slavish adherence to the '3-element' limit causes trouble. In the compounds above, inclusion of a little oxygen in the C–H–P case allows us to use the stable phosphate group as the acid function, and if we remove NF_3 from the C–F–N example, we obtain a nitrile, which is capable of functioning as a weak acid, thus :

$$H_2{-}P{-}CH_2{-}C{-}P{-}(OH)_2 \qquad F_2N{-}CF_2{-}C{\equiv}N$$

Approaching the problem in this way, it is possible to build up quite complex systems on paper, which do not go against any of the laws of Chemistry, and which if developed to their conclusion would provide the complexity needed for a living system. Before trying yet another approach, there is one fundamental limitation on any system that should be mentioned, since they have to evolve on a planet rather than be cooked up in the laboratory. This limitation is a thermodynamic one; in any mixture of elements or compounds, reactions will take place (at whatever speed – this is irrelevant) so that there is a net increase in entropy. Simply these reactions must liberate heat in order to go. In a C–H–O system, large amounts of oxygen result in any organic compounds being therodynamically unstable. That is, they tend to form carbon dioxide and water, and use up some of the excess oxygen. Our atmosphere is loaded with free oxygen, and many of the components of our bodies are thermodynamically unstable, even though it may take millions of years for the process to go to completion. Looking at this another way, life could not now evolve on Earth, since any organic compounds formed would be oxidized, rather than forming more complex organic compounds. The same applies on any planet where the element ratios are not suitable. Hence, on any planet it is not sufficient for it to possess the correct elements for chemical evolution. They must also be present in the correct proportions.

Transferring to the opposite side of the problem, that of the range of planetary conditions likely to be encountered by the battery of possible life forms, there are almost as many variations as there are planets. One of the most popular planetary conditions, for some reason, is low tempera-

TABLE 3. Possible structures for biochemicals in a chlorine-rich system.

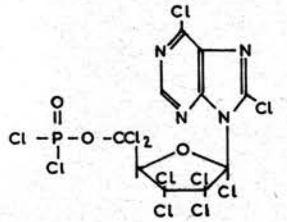
Biochemical type	Structure
Fatty acid	$R{-}CCl_2{-}\underset{\underset{\displaystyle O}{\Vert}}{C}{-}OH$
Amino acid	$R{-}\underset{\underset{\displaystyle NH_2}{\vert}}{CCl}{-}\underset{\underset{\displaystyle O}{\Vert}}{C}{-}OH$
Nucleotide	
Glyceride	$CCl_2{-}O{-}\overset{\overset{\displaystyle O}{\Vert}}{C}{-}(CCl_2)_n{-}CCl_3$ $CCl{-}O{-}\overset{\overset{\displaystyle O}{\Vert}}{C}{-}(CCl_2)_n{-}CCl_3$ $CCl_2{-}O{-}\overset{\overset{\displaystyle O}{\Vert}}{C}{-}(CCl_2)_n{-}CCl_2$
Protein	$\left(\underset{\underset{\displaystyle R}{\vert}}{CCl}{-}\underset{\underset{\displaystyle O}{\Vert}}{C}{-}NH \right)_n$

TABLE 4. The equivalent of the carbon cycle in other systems.

Terrestrial	$CO_2 \xrightarrow{H_2O} (CH_2O)_n\ ;\ CH_2O)_n \xrightarrow{O_2} CO_2{+}H_2O$
C-H-N ('Ammonia-life')	$CH_4 \xrightarrow{NH_3} C_xH_yCN\ ;\ C_xH_yCN \xrightarrow{H_2} CH_4{+}NH_3$
Si-Cl-N-H	$SiCl_4 \xrightarrow{N_2+HCl} (SiCl_2NH)_n;\ (SiCl_2NH)_n \xrightarrow{Cl_2} SiCl_4{+}N_2{+}HCl$
Si-H-O (Terrestrial analogue)	$SiH_4 \xrightarrow{H_2O} (SiH_2O)_m;\quad (SiH_2O)_n \xrightarrow{H_2} SiH_4{+}H_2O$
C-H-Cl-O	$CCl_4 \xrightarrow{H_2O} (CCl_2O)_n\ ;\ (CCl_2O)_2 \xrightarrow{Cl_2} CCl_4{+}O_2$

ture – perhaps because most of the planets in the Solar System are believed to be colder than our own. It has been suggested [9] that for existence in low-temperature environments, very reactive chemicals are needed so that the life-form can think at the same rate that we do, or at least can function at a similar rate. A chemistry based on the unstable diimine (HN=NH) was suggested. However, is it necessary that all forms of life should have the same time scale for their existence? Just because we take a few milliseconds to have a thought does not mean that this time is a universal constant for all thought. The rate at which we move is a function, eventually, of the rates of the chemical reactions of our metabolism. An amusing corollary of this is that since the rate of a chemical reaction doubles approximately for every 10 degrees rise in temperature, if we could raise our body temperatures to 47°C, we should think twice as fast.

The confusion may have arisen between the time required for an organism to evolve, and its metabolic rate. The first requires a fairly rapid process, since the Universe is believed to be not much older than the Earth, and any extremely slow process of evolution simply would not have had time for completion. The second can be as slow as may be, once the first part is completed. It is an amusing thought that somewhere there may be an organism that takes a million years to digest its dinner – but it is not so amusing to go to the other end of the scale. On high temperature planets, rapid reactions would be necessary to allow for repair of the rapid rate of heat damage of the structure – and consequently, rapid thought would be a corollary. We see a small version of this in the behaviour of cold-blooded species on the Earth. They are active in hot weather, sluggish in cold.

A related aspect of metabolic speed is the effect of pressure. Since increasing pressure brings reactants closer together (i.e., increases their concentrations), it also causes an increase in reaction rates. Thus, an organism under low-temperature/high pressure conditions could, using similar reactions to the terrestrial norm, have a similar time scale for its metabolism, if the two effects were properly balanced. If both high temperature and high pressure are the norm, as we believe is the case on Jupiter, reactions should be quite abnormally fast, unless a specific, slow biochemistry had evolved.

Alien Life Forms?

These are some of the possibilities. What then of the probablilities? Before any form of life can evolve, it needs suitable conditiions (obviously). We are somewhat ignorant as to what these may be, but we have an idea as to what conditions pertain on other planets. If we summarize these and fit our theoretical life forms to them, we should be able to get and idea about the probable nature of our co-inhabitants of space. Since the Earth may be an example of a rare case, they may be somewhat strange to us. Certainly there should be little prospect of disease, competition, or war from them!

Our Solar System contains 2 major classes of planet – the Earth-type and the gas giants. Apart from Earth itself, the prospect of life on the Earth-type planets is not very high. Venus and Mars could support life, as indicated in the previous article, but the *evolution* of life in a carbon dioxide atmosphere is difficult to imagine. It would be necessary to assume a primaeval atmosphere for these planets similar to that of the Earth, and there is no evidence for this. Mercury and Pluto are probably too hot and too cold, respectively; in addition, Mercury is lacking in atmosphere.

The giant planets are usually treated together as a group, but this is not a good approach since they differ amongst themselves as much as do Venus and Earth. More, in fact, since the mass ranges from 315 (Jupiter) to 14 Earth masses (Uranus). These planets are each interesting as possible abodes of life, and between them possess several sets of

TABLE 5: Elemental abundances in space.

Element	Abundance (11)* (Universal)	Abundance (10) (Planetary nebulae)
H	10^{12}	10^{12}
He	7.7×10^{10}	1.8×10^{11}
C	9×10^{7}	5.0×10^{8}
N	1.7×10^{7}	3.2×10^{8}
O	5.4×10^{8}	10^{9}
F	4×10^{4}	3.2×10^{5}
Ne	2.1×10^{7}	4.0×10^{8}
S	9.4×10^{6}	10^{8}
Cl	2.2×10^{5}	3.2×10^{6}
Ar	4×10^{6}	7.9×10^{6}

* Number of atoms per cm^3.

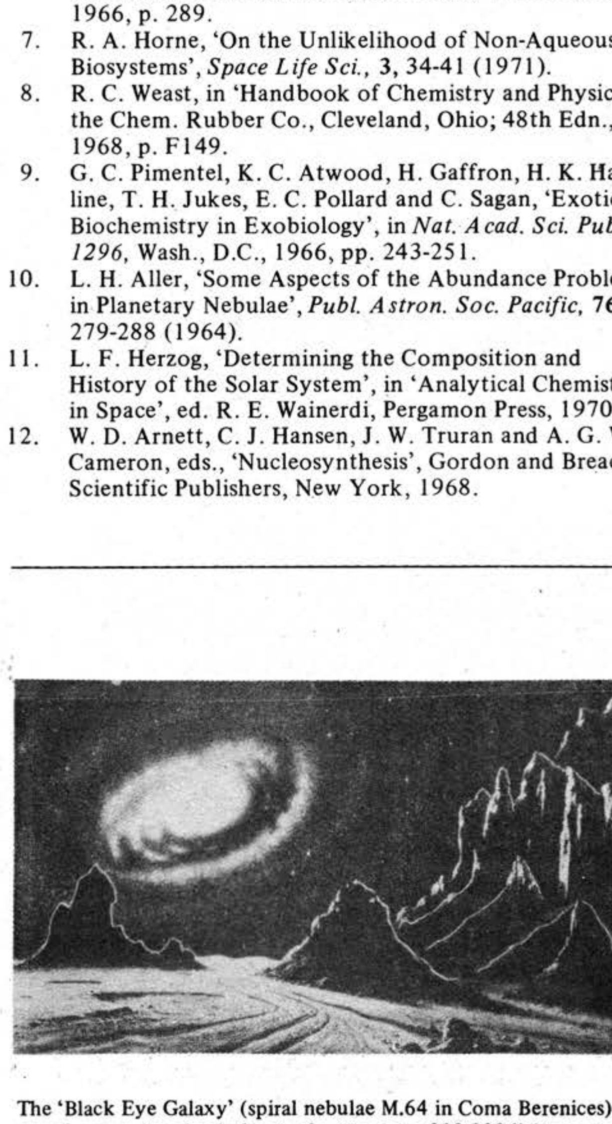
conditions. Jupiter has, in all probability, an aqueous cloud layer which could support water-based life; a high temperature/high pressure region where either water or ammonia could serve as the basic solvent for a living system; and a sea of hot supercritical liquid hydrogen containing small amounts of practically everything. Imagination fails when asked to describe chemical systems for these conditions – but not for theoretical reasons! Saturn is smaller and colder, and could be a base for liquid ammonia-based life. Uranus similarly, but the temperature is much lower. Neptune could have liquid methane with the ammonia, and is colder still.

What of the planets of other stars? It may be true that the region of space around us has a composition such that any planets condensing will have a similar distribution and composition to the Solar System. It is interesting that the planets of the Solar System are not more similar to one another, and this suggests that the forces causing the condensation of planets also cause a separation in their constituents. If this is general, we would expect a wide range of planetary properties within every system. If the planets and the Sun originally formed at the same time from the same nebula, and this is true for other systems, it should be possible to analyse other nebulae and thus determine the probable composition of their planets. The only formation of this sort available at the moment refers to planetary nebulae rather than the dark nebulae from which it is likely that planets are being formed [10], but it is presented in Table 5, together with the Suess-Urey figures for 'universal' composition [11]. It can be seen that the figures are quite similar, making it look as though any form of life in the galaxy near to us will be formed like ourselves – although this argument is extremely tenuous.

A more fruitful approach concerns modern theories of stellar evolution and nucleosynthesis [12]. Some stars have been found which are rich in calcium, mercury, silicon, manganese, etc., usually just one or two elements; some are extremely oxygen-deficient. If any of these became supernovae, the planets eventually forming the remaining dust cloud would have an interesting composition. Also, during nova and supernova exposions, elements are synthesized by various processes which depend on the temperature and composition of the star; whole regions of space could have an over- or under - abundance of one or more elements. It may be that terrestrial life is the exception rather than the rule. Perhaps we should start getting used to the idea!

REFERENCES

1. P. Molton, 'Spontaneous Generation and Chemical Evolution', *Spaceflight*, May 1972, pp. 187-191.
2. P. Molton, 'Exobiology, Jupiter, and Life', *Spaceflight*, June, pp. 220-223.
3. P. Molton, 'The Limitations of Terrestrial Life', *Spaceflight*, January 1973, pp. 27-29.
4. V. A. Firsoff, in 'Life Beyond the Earth: A Study in Exobiology', Basic Books, Inc., New York, 1963, pp. 122-128.
5. C. W. Bird and P. Molton, 'An Alternative to Terrestrial Biochemistry', in preparation.
6. G. Wald, in 'Extraterrestrial Life: An Anthology and Bibliography', compiled by E. A. Shneour and E. A. Ottersen, *Nat. Acad. Sci. Publ. 1296A*, Wash., D.C., 1966, p. 289.
7. R. A. Horne, 'On the Unlikelihood of Non-Aqueous Biosystems', *Space Life Sci.*, **3**, 34-41 (1971).
8. R. C. Weast, in 'Handbook of Chemistry and Physics', the Chem. Rubber Co., Cleveland, Ohio; 48th Edn., 1968, p. F149.
9. G. C. Pimentel, K. C. Atwood, H. Gaffron, H. K. Hartline, T. H. Jukes, E. C. Pollard and C. Sagan, 'Exotic Biochemistry in Exobiology', in *Nat. Acad. Sci. Publ. 1296*, Wash., D.C., 1966, pp. 243-251.
10. L. H. Aller, 'Some Aspects of the Abundance Problem in Planetary Nebulae', *Publ. Astron. Soc. Pacific*, **76**, 279-288 (1964).
11. L. F. Herzog, 'Determining the Composition and History of the Solar System', in 'Analytical Chemistry in Space', ed. R. E. Wainerdi, Pergamon Press, 1970,p.8.
12. W. D. Arnett, C. J. Hansen, J. W. Truran and A. G. W. Cameron, eds., 'Nucleosynthesis', Gordon and Breach Scientific Publishers, New York, 1968.



The 'Black Eye Galaxy' (spiral nebulae M.64 in Coma Berenices) seen from an imagined planet of a star some 200,000 light years outside the main system. This painting by David Hardy, FRAS, AFBIS, is published as a litho print by Rosenstiel's, 22 x 36 in., and is available price £2.65 post paid (U.K.) from: Astro Art, Low Road, Haddiscoe, Norwich, NOR 29W, England.

THE LAST APOLLO – 3

By David Baker

Concluded from March issue, page 91].

Transfer of Moon Samples

For more than 3 days Ronald Evans had monitored an array of scientific experiments aboard the command ship 'America' extending the work of the surface explorers. Now, with the ascent stage of 'Challenger' safely docked on the nose of the mother ship, the men transferred the Moon samples and film magazines and stowed them aboard. Soon the frail craft that had borne Cernan and Schmitt from the Moon would be cast adrift to head for destruction on the eastern slopes of the South Massif, not far from where they had trod the valley of Taurus-Littrow a mere day before.

At last the men could enjoy a long sleep, though the crew still had nearly 2 days of scientific work ahead of them in lunar orbit before they could leave for home.

Orbital Experiments

For more than 6 days the command and service modules swept around the Moon, scanning, photographing, probing and observing the dusty terrain below. A complex battery of sensors, unlike any flown hitherto, gave promise of adding a new dimension to Man's understanding of his celestial neighbour. Broadly speaking these could be categorised into photographic and geophysical tasks.

The camera equipment in the Scientific Instrument Module was identical to that carried on the previous 2 missions and reference to the appropriate flight reports will provide background data on this apparatus.

One of the most important capabilities of the CSM lay in its ability to contribute gross geophysical data about the Moon. Long lunar orbit durations have proved invaluable in Apollo 15 and 16 for making wide-scale surveys of the surface. One experiment on Apollo 17, the Lunar Sounder, would seek to find the nature of the sub-surface. Housed at the aft end of the SIM bay the equipment consisted of a coherent synthetic aperture radar, an optical recorder, and 3 antennae.

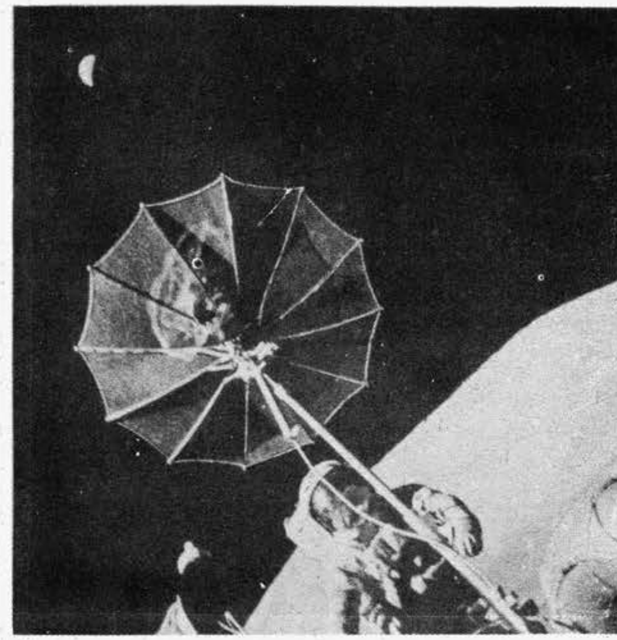
The Lunar Sounder uses a radar interferometry technique for propogating radio waves to the lunar surface and comparing the changes brought about by the various sub-surface layers. In this way it is possible to build up a picture of the different elements beneath the surface and by timing the reflected wave thereby determine the depth of penetration, using a laser altimeter to accurately establish the orbital height.

The coherent synthetic aperture radar transmitted signals in 5.15 and 150 MHz waves via 2 sections of a dipole antenna and a single Yagi. The dipole antenna was unreeled from either side of the base of the service module some 34 ft. 2 in. to provide an effective span of 80 ft. The 7-pole Yagi was extended some 9 ft. from the base of the SIM bay and lay perpendicular to the dipole.

Less than 0.001 sec. after transmitting a pulse the radar was turned off while the waves travelled to the surface, penetrated up to 1.5 km, and were received back at the spacecraft for delivery to the optical recorder. Here the signal was amplified, converted to light waves and turned through 180° for recording by a film cassette to be retrieved during the trans-Earth EVA.

The equipment could be operated in the HF receive-mode only, listening to the galactic background noise at 150 MHz. The Lunar Sounder was only operated when all other orbital science instruments were dormant.

One important parameter essential to a gross understanding of the geophysical nature of the lunar surface was the thermal balance established by differing minerals. By comparing the temperature of localised areas with the phase angle of the Sun, it was possible to determine the regional characteristics, detect local 'hot spots' and infer the structural composition directly resulting from the measured thermal properties.



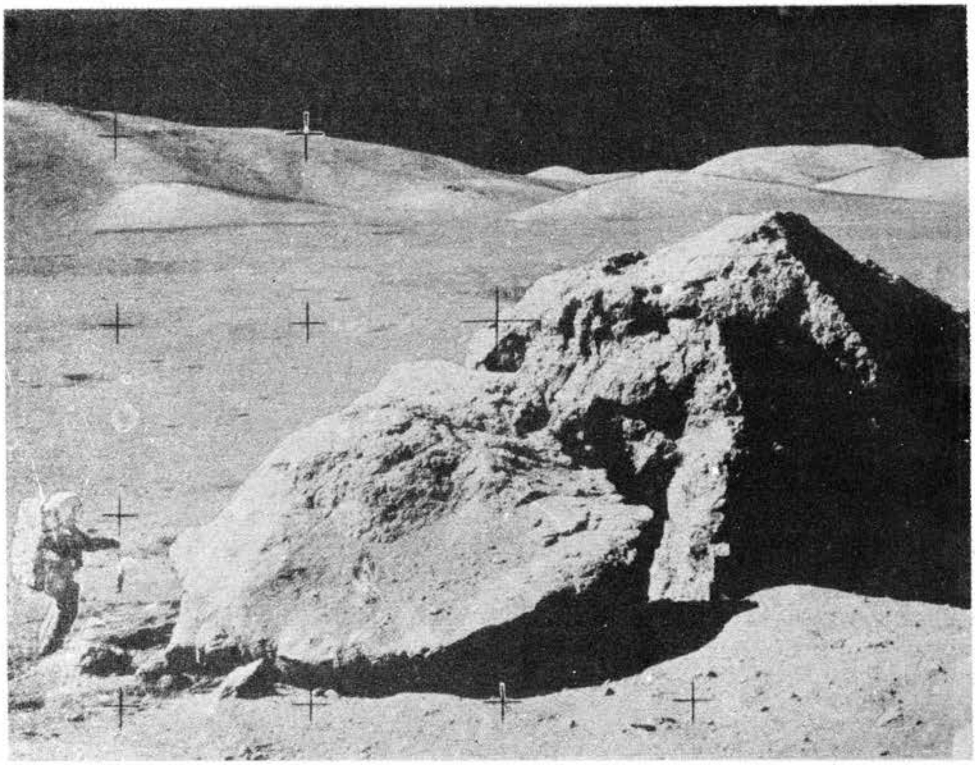
Apollo 17 commander Eugene Cernan stands beside the lunar rover during the third EVA at Taurus-Littrow. A half-Earth looks down from top left.

All pictures National Aeronautics and Space Administration.

To provide this kind of data Apollo 17 carried an Infrared Scanning Radiometer, located at the base of the SIM bay. The optical scanning unit contained a Cassegrain folded telescope which directed the light beam on to an Ebert mirror, back to a grating assembly and through an exit slit to the thermister bolometer where an electrical signal was obtained and processed through the electronics. The mirror continually swept a 162° area across the ground track and recorded temperatures over a range of -213°C to +127°C with a sensitivity of 1°C. The 2 km resolution achieved by the ISR was a considerable improvement on the 15 km currently established by Earth-based instruments which, to date, have obtained a thermal resolution of only 50°C. The electronics of the ISR channelled the recorded temperatures into 3 telemetry bands representing thermal ranges of 0-160°K, 0-250°K and 0-400°K.

Probing the Lunar 'Atmosphere'

Attempts on earlier flights to detect and quantify random gases present in the Moon's 'atmosphere' have been restricted to localised surface experiments in the ALSEP arrays, or the mass spectrometers of Apollo 15 and 16. 'America' carried a Far Ultraviolet Spectrometer (UVS) for scanning the surface and seeking possible traces of elements such as hydrogen, carbon, nitrogen, oxygen and krypton. Already the Cold Cathode Ion Gauge of Apollo's 12, 14 and 15 had



Geologist Harrison Schmitt examines a split boulder which shows a complex formation history at Station 6 at the base of North massif. The block seems to have crystalized directly from a melt and does not appear to be a breccia broken by impact.

shown local increases of 10 - 100 times normal lunar pressure, and the spectrometer on Apollo 15 had detected radon emissions from the crater Aristarchus. By measuring the resonant radiation of atoms present on the sunlit side, and monitoring dark side fluorescence, the equipment on-board Apollo 17 could build up a total groundtrack picture of the atmospheric particles. Correlation of this data with that of the radiometer may display significant parallels between gas emission and thermal variations.

The spectrometer received radiation in the range of 1175 to 1675 A through a folded Cassegrain telescope, reflecting this through an optical grating containing 36 K lines/cm on to an Ebert mirror and back through an exit slit on to a photomultiplier. The signals were processed in the electronics section for transmission to Earth. The instrument had a 12 x 12° field of view forward of the spacecraft's vertical axis.

All 6 experiments (24 in. panoramic camera, 3 in. mapping camera, laser altimeter, infrared radiometer, lunar sounder, and UV spectrometer) were contained within the exposed sector of the service module and controlled by Evans from controls on the main display console.

Several other devices were carried in the command module. A sodium iodide crystal, identical to that used as the scintillat in the gamma ray spectrometer of Apollo 16, measured the background flux to assist with calibration of the earlier boom measurements. The tracking network on Earth conducted a detailed study of the variations in lunar gravity by recording signals from the Doppler tracking of the CSM/LM, the lone CSM, and the descent of the LM ascent stage after jettison. Even the windows of the command module presented an opportunity for studying the flux rate of meteoroid craters down to 10^{-12} gram mass. Post flight analysis of the events contribute to a better understanding of the cislunar environment.

Biological Experiments

During the long hours of lone lunar orbit, command module pilot Evans was not the only animal object present in the spacecraft. Five pocket mice, natives of Palm Springs, California, accompanied him. Sealed in a perforated aluminium tube, 12 in. long and 7 in. wide, the 5 mice fed from seeds and obtained their oxygen from a potassium superoxide tube activated by exhaled CO_2. The experiment, called Biocore, required cosmic ray particle detectors to be implanted under their scalps to determine the effect of cosmic ray ionisation on the nerve cells of the brain. Post flight post mortems were to reveal the result.

Finally, Biostack, a cylinder containing biological materials, repeated the experiment of Apollo 16 by determining the effect of high-energy heavy ions on 6 test layers.

The Return Flight

Before the exuberant and philosophical Cernan and Schmitt had left the lunar surface, Evans had fired up the SPS engine for 18 seconds to change the orbital plane by 3.6°, bringing the CSM into plane acquisition of the ascent stage and setting up the orbit for the following 2 days of orbital science.

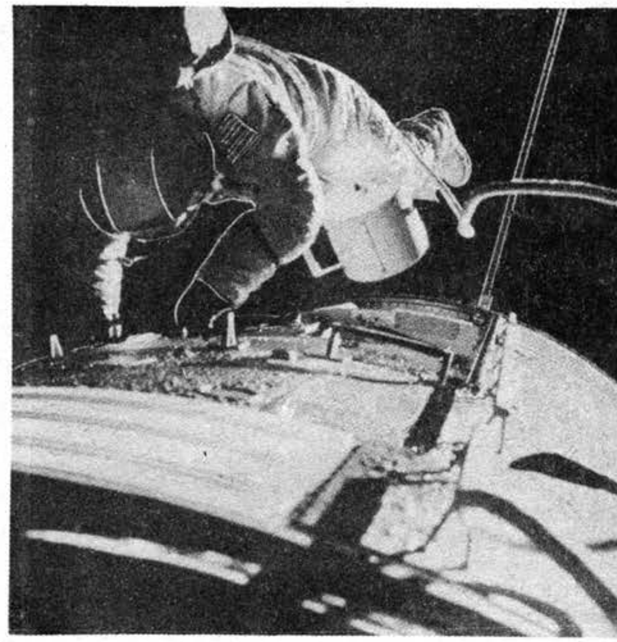
Two rest periods and 45½ hrs. after Cernan and Schmitt had departed from the lunar surface, Evans fired the SPS engine for the last time in the Apollo Programme and headed back toward Earth. The last TV views of the receding Moon were made and not without a certain regret that Man was retracting his energies at a time when he had just achieved the centuries-old dream of exploring other worlds.

Housekeeping duties, navigation sets, exercise periods, eat periods, sleep periods, lone moments of quiet contemplation: such was the lot of the final trio of Apollo astronauts. There was, of course, one main duty. Shortly after 253½ hrs. after launch nearly 11 days before, Evans depressed the

command module, opened the hatch, and slowly drifted out along the service module to retrieve the 2 camera cassettes and the Lunar Sounder records.

En-route for home the crew performed heat flow and convection experiments using 3 test cells for measuring and observing fluid flow characteristics under zero-g, previewing the Skylab experiments for 1973. They repeated the light flash experiment by donning the ALFMED, a 2-piece board containing emulsion plates for measuring cosmic ray tracks, continued with their controlled food intake, required for endocrinological analysis of metabolic balance, and scanned galactic targets with the UV spectrometer – now defunct from its prime role in lunar science.

Shortly before reaching Earth the crew held a press conference with the TV camera observing them huddled against the navigation bay. So accurate was the return trajectory that only a single reaction control system manoeuvre was necessary to trim the flight path. Prior to separation of the service module Evans donned a caridiovascular conditioning garment, so called for its pressure retention qualities, in support of studies to determine the possible insulation from g effects such a garment could provide.



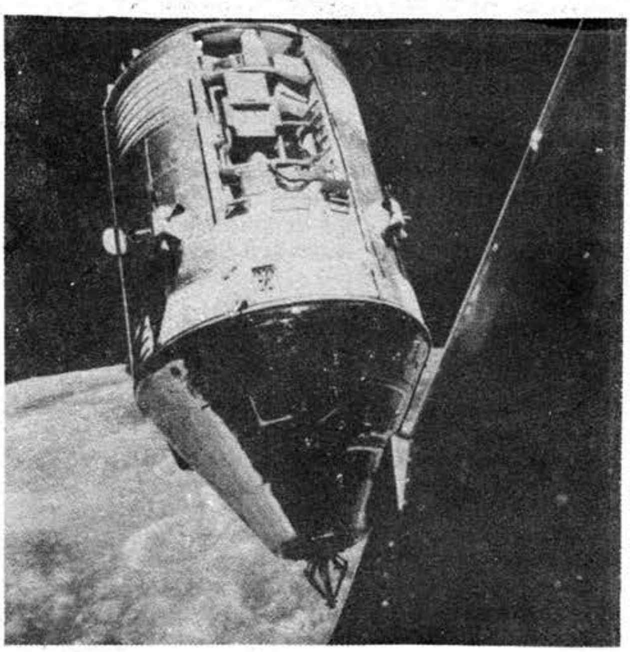
After leaving lunar orbit on the return flight Ronald Evans space walks to the SIM bay to recover film cannisters.

Splashdown

With smooth precision the final events before splashdown cycled off uneventfully and right on schedule. At 19: 24 GMT on 19 December 1972, the command module settled into the Pacific waters to complete the longest lunar flight of them all. In just 301 hr. 51 min. astronauts Cernan, Evans and Schmitt had travelled across a quarter-million miles to plant the US flag on a 6th lunar landing site, gather 250 lb. of samples, install 5 elements of a scientific research station and perform 26 experiments.

The last Apollo had come to Earth, and the record was impressive. In 2,502 hours of spaceflight the Apollo Programme had run its course. The total NASA manned spaceflight programme had accumulated more than 3,649 hours mission time. Yet more significant than all of this is the legacy left behind by a decade and more of exploring cosmic space. Little more than 5 hr. after Apollo 16 lifted off from Cape Kennedy, Ken Mattingley left a comment for posterity: 'I tell you, God didn't equip us with enough eyes to see everything there is to see'. One day the legacy of Apollo will be heeded and the words of Robert Frost born again in the hearts and minds of a future generation: ....'I have promises to keep, and miles to go before I sleep,

As Cernan and Schmitt manoeuvre their lunar module ascent stage closer to the mother ship 'America' to re-dock in lunar orbit, they capture a full view of the exposed SIM bay in the side of the service module.



Acknowledgements

The author wishes to thank the National Aeronautics and Space Administration, and the many institutions related to the Apollo programme, for many years of helpful co-operation contributing to the preparation of flight records.

GENERAL STAFFORD

Astronaut Thomas P. Stafford, who commanded the Apollo 10 mission to the Moon, as a final orbital dress rehearsal for the first Moon landing, has been promoted to Brigadier-General in the US Air Force. The veteran of 3 space flights he is the youngest officer of flag rank in any of the US services. General Stafford will continue to serve as Deputy Director of Flight Crew Operations at the Manned Spacecraft Center. He has logged 290 hr. 15 min. in space.

NEXT MONTH

The May issue of *Spaceflight* will include the first of a new series entitled, 'Evolution of the Space Shuttle', by David Baker.

SPACE REPORT

A regular monthly review of Space Events and Technical Trends

APOLLO MISSION RECORDS

These are the records set by Apollo 17 during the 6th and final Moon landing mission.

Time on the Moon: 74 hours, 59 minutes for Eugene A. Cernan and Harrison H. 'Jack' Schmitt, breaking the record of 71 hours, 2 minutes set by John W. Young and Charles M. Duke, Jr., on Apollo 16. Altogether, in 6 missions, Apollo astronauts spent 12 days, 11 hours, 34 minutes on the lunar surface.

Time exploring the surface: 22 hours, 5 minutes, surpassing the record of 20 hours, 16 minutes set by Young and Duke on Apollo 16. The total for all Apollo astronauts: 3 days, 7 hours, 54 minutes.

Longest single Moonwalk: 7 hours, 37 minutes, bettering mark of 7 hours, 23 minutes set by Young and Duke on Apollo 16.

Amount of rocks and soil collected: estimated 249.5 lb. breaking record of 208 lb. by Apollo 16. Total rocks collected by all missions: about 832.5 lb.

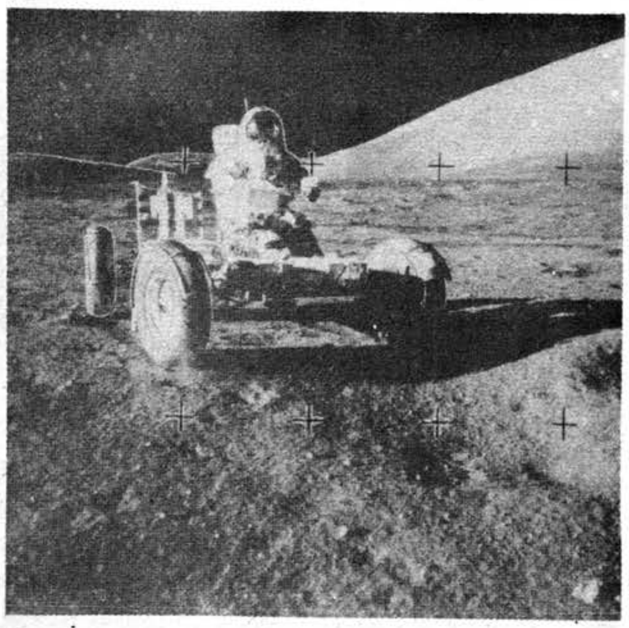
Moon surface speed record: 11.1 miles per hour by Cernan in Rover 3, breaking that of 10.5 m.p.h. by Young in Rover 2 on Apollo 16.

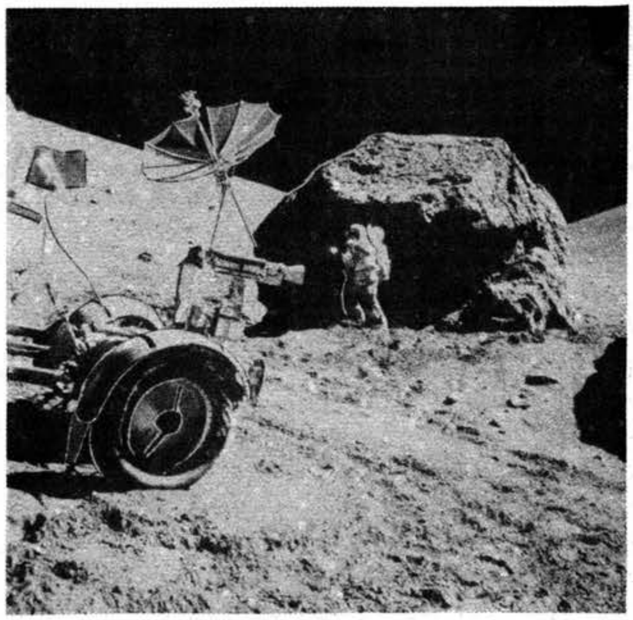
Moon distance record: 19.9 miles travelling in Rover 3, breaking mark of 17.3 miles in Rover 2 on Apollo 16. The 3 Rover vehicles travelled a total of 52.21 miles.

Time in lunar orbit: 6 days, 3 hours, breaking record of 6 days, 1 hour set by Apollo 15. In 8 Moon flights, astronauts spent 30 days in lunar orbit.

Length of Apollo missions: 12 days, 13 hours, 51 minutes, shattering record of 12 days, 7 hours, 11 minutes on Apollo 15. The 11 Apollo flights have lasted 104 days, 5 hours, 3 minutes.

Fine dust sprays from the wire-mesh wheels of the lunar rover as Cernan checks the vehicle during the first EVA at Taurus-Littrow. The eastern end of the South Massif looms in the background.





The vehicle parked near the split boulder investigated at Station 6 during the third EVA. Note TV camera and high-gain directional antenna.

US/USSR Manned Space Flights, inclusive of Soyuz 11 and Apollo 17

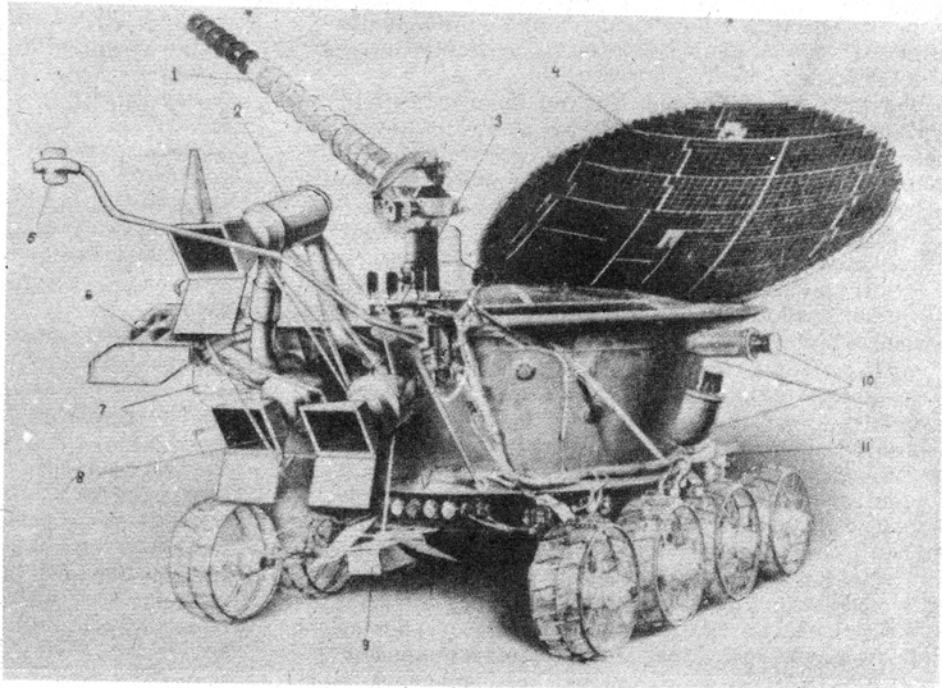
US	27 flights	with 34 astronauts:-	
	2 astronauts	with 4 flights:	Lovell, Young
	5 astronauts	with 3 flights:	Schirra, Conrad, Stafford, Scott, Cernan.
	9 astronauts	with 2 flights:	Grissom, Cooper, McDivitt, Borman, Armstrong, Collins, Gordon, Aldrin, Shepard
	18 astronauts	with 1 flight:	Glenn, Carpenter, White, Eisele, Cunningham, Anders, Schweickart, Bean, Haise, Swigert, Roosa, Mitchell, Worden, Irwin, Duke, Mattingly, Schmitt, Evans. (12 worked on surface of Moon).
USSR	18 flights	with 25 cosmonauts:-	
	2 cosmonauts	with 3 flights:	Shatalov, Yeliseyev
	3 cosmonauts	with 2 flights:	Komarov, Nikolayev, Volkov
	20 cosmonauts	with 1 flight:	Gagarin, Titov, Popovich, Bykovsky, Tereshkova, Feoktistov, Yegorov, Belyayev, Leonov, Beregovoy, Volnyov, Khrunov, Garbatko, Filipchenko, Kubasov, Shonin, Sevastyanov, Rukavishnikov, Dobrovolsky, Patseyev.

Lunokhod 2, which soft-landed on the Eastern rim of the Sea of Serenity on 16 Jan. weighed 1,840 lb. (840 kg) at launch, about 220 lb. (100 kg) heavier than Lunokhod 1 which operated on the Sea of Rains for 10½ months from 17 Nov. 1970, see *Spaceflight*, Mar. 1971, pp. 90-91; Jun. 1971, pp. 204-205.

Key is as follows:

1. Narrow-beam directional antenna
2. Panoramic TV camera with lens hood and dust cover.
3. Photo receiver.
4. Hinged solar cell panel (producing electricity from sunlight).
5. Magnetometer.
6. French-built laser refelector.
7. Astrophometer.
8. Stereoscopic pair of TV cameras with lens hoods and dust covers.
9. 'Rifma' chemical soil analyser (in retracted position).
10. Telephometers.
11. Surface evaluator/soil probe.

Novosti Press Agency



LUNOKHOD 2

Proceeding at speeds nearly double those of its predecessor, Lunokhod I, the Soviet Union's new Moon vehicle, Lunokhod 2, has been carrying out its first explorations on the Moon, on the eastern fringe of the Sea of Serenity.

When the 8-wheeled vehicle, at 4.14 a.m. (Moscow time) on 16 Jan. moved down the gangway which took it from the Luna 21 landing stage in the Lemonnier crater, the 'driver' at the Soviet control centre had a good view of the surrounding lunar landscape.

Lunokhod 2 was on a smooth plain between two small craters. On the horizon were a number of peaks of the Taurus Mountains, not very high and, in the opinion of scientists, not more than 6 km. from the landing site.

Several metres ahead of the Moon vehicle was a small crater with a diameter of about 15 metres. When Lunokhod 1 set out on its travels in the Sea of Rains in Nov. 1970, the problem of negotiating an obstacle of that kind would have been the subject for keen debate, but this time, with the experience already gained, the ground crew took it in their stride and half an hour later the vehicle had covered a distance of nearly 30 metres. They selected a flat area and swung the vehicle round to face the Sun and recharge its solar batteries.

Another radio communication session was held with Lunokhod 2 on the night of 17 Jan.

The X-ray radiation of the Sun and the illumination of the sky were measured by means of instruments and the first estimates were made of the mechanical properties of the lunar rock at the landing site.

During further radio communication sessions on 20-21 Jan. scientific instruments were switched on and operations were carried out to prepare Lunokhod 2 for the lunar night.

Panoramic pictures were used to select a suitable parking place.

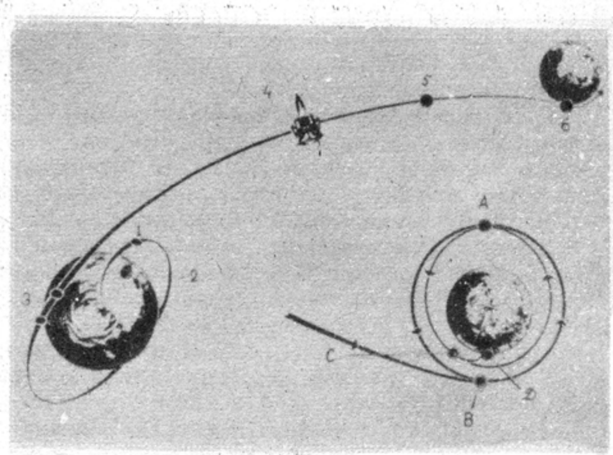
LUNA 21 FLIGHT PROFILE

Key:
1. Launched by Proton rocket from Tyuratam 9.55 a.m. (Moscow time) 8 Jan. 1973.
2. In parking orbit.
3. Trans-lunar injection.
4. First course correction 9 Jan.
5. Second course correction.
6. Braking into lunar orbit 90 – 110 km inclined at 60° to equator; period 1 hr. 58 min. 12 Jan.

A. Thrust correction adjusts orbit of Luna 21 to give closest distance to lunar surface of 16 km 13-14 Jan.
B. Braking into lunar orbit.
C. Second braking.
D. Landing inside Lamonnier crater Eastern rim of Sea of Serenity 1.35 a.m. (Moscow time) 16 Jan.

(Note: Soviet letter key is not in sequence).

Novosti Press Agency.



In the course of a 6 hour communication session on the night of 19-20 Jan. Lunokhod 2 had covered a total distance of 1,148 metres.

During the session the vehicle moved in a south-easterly direction towards the 'coast' of the Sea of Serenity, where the mountains encircling the Lemonnier crater rise. This journey took the vehicle to a distance of 1,050 metres from the landing stage. During the session the ground crew steered the vehicle along the route at different speeds, carried out various manoeuvres and bypassed natural obstacles. The rock along the route varied as regards its mechanical characteristics. There were sections where it was firm and others where there were deep layers of loose rock.

After completing its programme of exploration for its first lunar day, Lunokhod 2 came to a halt on the edge of a crater more than 1 km from the Luna 21 landing stage. The rover remained stationary throughout the lunar night, for about a fortnight, although, during that time it continued to function as a stationary observatory. It was well protected from the cold of the lunar night, during which the temperature dropped to -140°C. Its electronic systems are heated by a nuclear source.

The landing area of the automatic station Luna 21 was thoroughly studied and a number of panoramic photographs of the spot were taken, together with stereoscopic photographs of this interesting part of the Moon. According to finalised data, the craft landed on a basalt plain, at a point about 10 km from the 'mainland'.

During its first lunar day Lunokhod 2 moved more than a kilometre away from the landing site. It travelled over a comparatively smooth area of the surface.

A study of the magnetic field on the Moon's surface is one of the interesting new experiments being carried out for the first time. The magnetometer functions regardless of whether the vehicle is moving or stationary.

The investigations started by Lunokhod 2 will help to shed light on a number of important features of the magnetism of the Moon and will provide information about the electromagnetic properties of its interior.

Further information on the movement and research programme of the remote-controlled rover will appear in our 'MILESTONES' feature.

X-24B – FLIGHT TESTS BEGIN

The X-24B experimental lifting body will be flown in a joint Air Force-NASA flight research programme at Edwards Air Force Base, California, beginning this month. About 30 flights are planned extending into 1975.

Goal of the programme is testing a wingless craft's handling qualities for an extended near-Earth flight and for conventional runway approach and landing. The X-24B, modified from the earlier X-24A, also is usable for flights from Earth to extreme altitudes, and speeds 5 times that of sound.

In the present test programme, however, the craft will be flown no faster than about Mach 1.5 to obtain performance data primarily from 900 miles per hour down to landing speed.

For the test flight, the X-24B will be carried to 45,000 ft. by a B-52 aircraft. After separating from the B-52, it will be boosted to 60,000 ft. and a speed of Mach 1.5 by a 130-sec. burn of its liquid propellent rocket motor, and then will glide to Earth.

The X-24B uses the cockpit, engine, basic structure, and subsystems of the X-24A. The main change is a new aluminium alloy exterior structure which gives it a delta shape and doubles its lifting surface. The X-24A's ability to manoeuvre about 1,000 on either side of its flight path increased almost three-fold in the X-24B due to its improved aerodynamic shaping.

Under contract to the Air Force, Martin Marietta designed and built the X-24A, which made 28 flights from 1969 - 71. Detail design and structural modifications for the X-24B also were done by Martin Marietta with Air Force-NASA funding.

The X-24 programme, both A and B, have involved 4 organisations. At Wright-Patterson Air Force Base, Ohio, the Aeronautical Systems Division and the Flight Dynamics Laboratory have carried out overall management and technical responsibilities for the programme. Flight test activities have been conducted at Edwards', the Air Force Flight Test Center and NASA's Flight Research Center.

Martin Marietta also built the earlier unmanned lifting body designated as PRIME (Precision Recovery Including Manoeuvring Entry) used for design development flights in 1966 and 1967, and developed ablative coating for the X-15 research rocket plane.

Table 1. USAF/NASA X-24B: Principal Features.

Shape:	Triangular body cross section, flat bottom and rounded top; double delta planform of 330 ft^2; 3 vertical fins.
Structure:	Glove of conventional aluminium alloy attached to X-24A structure.
Length:	37 ft 6 in.
Height:	10 ft 4 in.
Span:	19 ft 2 in.
Weight:	Unfuelled – 7,800 lb. Fuelled – 13,000 lb.
Cockpit: (unchanged)	Pressurized to 3.5 psi. Jettisonable canopy. Zero-zero ejection seat. Conventional stick and rudder/brake pedals.
Controls:	Upper and lower flaps (elevator, pitch trim). Ailerons (aileron, roll and pitch). Dual rudders. Full power irreversible dual hydraulic systems. Redundant 3-axis stability augmentation system.
Propulsion: (unchanged)	Thiokol XLR-11, 8000-lb thrust. Bell LLRV, two 400-lb thrust optional landing rockets.
Landing gear:	Conventional main wheels (unchanged); new nose wheel (from the F-11).
B-52 attachment:	Martin Marietta adapter to X-15 pylon.

MARS UNVEILED

Introduction

The Mariner 9 spacecraft which reached Mars on 13 November 1971 circled the planet 698 times in 349 days, gathering a wealth of science data that has revised all previous concepts of Mars. For more than half a Martian year, the spacecraft maintained an instrumented surveillance of the planet as the seasons changed beneath its cameras.

Some of the major observations of the mission, which ended on 27 October 1972, were:

(a) A geologically active planet with volcanic mountains and calderas larger than any on Earth.
(b) An equatorial crevass 4,000 km (2500 miles) long and three to four times the depth of the Grand Canyon.
(c) Indications that free-flowing water may have existed in Mars's geologic history.
(d) The evolution of a monumental dust storm that raged to an altitude of 50 - 60 km (30 - 35 miles) above the surface, and
(e) The realization that dust storms and cloudiness account for much of the puzzling variability in Mars's appearance over the years.

These findings lay the groundwork for America's next venture to Mars, project Viking which seeks evidence of life on the surface.

Flight Profile

The Mariner Project, managed for NASA's Office of Space Science by the Jet Propulsion Laboratory in Pasadena, California, was planned around a two-spacecraft mission to Mars during the 1971 launch opportunity. Mariner 8 and Mariner 9 were designed, built, and tested at JPL and launched from Kennedy Space Center, Florida, in May 1971.

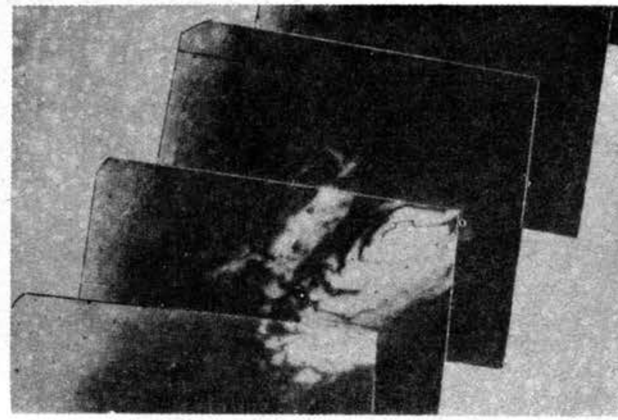
The second stage of the Atlas-Centaur Launch Vehicle failed during the early minutes of Mariner 8's flight on 8 May. Plans were revised to allow the remaining spacecraft to conduct the missions of both Mariners.

Mariner 9 was launched successfully on 30 May. A trajectory correction manoeuvre on 5 June was made so accurately that no additional corrections were necessary during the 167-day Earth-to-Mars flight.

Dust Storm on Mars

As the spacecraft approached the planet in mid-Nov, its TV cameras took 3 series of pictures while Mars revolved several times on its axis. The pictures verified the existence of a colossal dust storm that had enveloped the entire Martian globe. The gathering storm had been watched for about two months by Earth-based astronomers. This peculiar condition of Martian weather was to persist for nearly 6 weeks more, delaying the planned mapping sequences but allowing scientists to study the meteorological phenomenon. They found that the effect of large amounts of dust in the atmosphere was to cool the surface and warm the atmosphere. As it turned out this was a measurement of great value to scientists who have long been trying to calculate the effect of increasing pollution on Earth's global climate.

On 13 Nov. 1971, Mariner 9 had completed the 397-million km (248-million mile) interplanetary crossing and was inserted into orbit around Mars by a 15-minute firing of its rocket engine. It had become the first man-made object to orbit another planet. (Soviet spacecraft Mars 2 and Mars 3 arrived later in November).



Entire south polar cap of Mars photographed by Mariner 9 during its fifth orbit of the planet.

An orbit trim manoeuvre was executed during the 4th revolution, refining Mariner's average orbital period to 11.97 hr The post-trim periapsis (low point in the orbit) was 1387 km (862 miles). An orbit inclination of 65 deg. was selected so that Mariner could map more than 70% of the planet and examine its variable features.

During the first 6 weeks of orbital operations Mariner's instruments were peering down through the most extensive dust storm observed on Mars since 1924. Only the bright waning ice cap at the south pole and four dark mountain peaks were visible through the planet-wide haze. Later photos revealed the 4 dark spots were giant volcanic mountains with large caldera-type craters at their peaks. One, Nix Olympica, is about 500 km (300 miles) across at the base and its peak stands at least 17 km (10.5 miles) above the surrounding plain.

Phobos and Deimos were photographed close-up for the first time. The tiny Martian moons were found to be synchronous with Mars (one side always facing the planet). Both moons are heavily cratered, apparently from meteoroid impacts.

Owing to a previously unknown gravity field variation in Mars' equatorial plane, the orbital period was found to be slightly too short, gradually changing the time relationship of the periapsis to the Earth tracking stations.

The dust storm continued beyond most predictions, and so it became apparent that the planned mapping of the planet could not be completed during Mariner 9's basic 90-day mission.

Between Christmas 1971 and New Year's Day, the Mariner cameras and the other instruments all detected a large-scale clearing of the dust storm. The entire mission was revised to begin mapping the surface on 2 January 1972.

A second trim manoeuvre was made on 30 December 1971, correcting the orbital period for co-ordination with the 64-metre (210-ft) antenna at the Goldstone station of the Deep Space Network. The manoeuvre also raised the periapsis to 1650 km (1025) miles), allowing broader camera coverage and permitting the mapping objective to be achieved.

The Storm Clears

During the first few weeks of January, the Mariner instru-

Mosaic of pictures from Mariner 9 of the equatorial region of Mars showing part of the enormous Coprates rift valley running vertically through the picture. The valley is 2,500 miles long, 75 miles wide and in places nearly 20,000 ft. deep – three to four times that of the Grand Canyon in Western America. North is at left.

Jet Propulsion Laboratory.

ments looked at a brand new target, a clear Mars. The pictures revealed a shrinking south polar cap; sinuous channels which appeared to be water-cut; so-called 'chaotic' terrain first seen in 1969 by Mariner 6 and Mariner 7; and huge impact craters, their floors covered with wind-blown dunes.

On 12 January, a swath of mapping pictures included a photograph of a 480 km (300 mile) section of a vast chasm near the equator with branching canyons eroding the adjacent plateau-lands. Later, overlapping sequences showed that the chasm stretches some 4,000 km (2500 miles), nearly one-fourth the circumference of the Martian globe. Mariner's ultra-violet spectrometer measured the chasm depth at nearly 6 km (20,000 ft).

By mid-March photo, thermal and chemical maps covered nearly 85% of the planet and plans were made for an extended mission through the summer and fall of 1972.

From 2 April to 4 June, Mariner's science instruments were turned off while the spacecraft's orbit took it into Mars's shadow during each twice-a-day revolution. These frigid solar occultation periods, which Mariner 9 was to survive, ranged from a few seconds to nearly 100 minutes per orbit.

The spacecraft cameras and other instruments were operated again on 11 June, recording the first of 10 additional complete tapeloads of pictures and other data. Extended mission targets included the north polar region which was not visible earlier in the year, features that vary as the Martian seasons change, and possible landing sites for the Viking 1975 Project.

Mapping coverage was extended to 100% of the planet. The final playback of pictures was received at JPL on 17 October and brought the total number of photos to 7329.

Mariner 9's mission ended on 27 October when engineering telemetry signals ceased during the craft's 698th revolution. Distance from Earth at that time was 383,675,000 km (238,416,000 miles). Stored in its tape recorder were another 15 pictures and related science data which had been taken the day before. The spacecraft's supply of attitude control gas was depleted just minutes before Mariner was to play back the final tapeload of data. Engineers at JPL sent the final signal – the last of 45,960 commands – to turn off Mariner's radio transmitter. Mariner 9 is expected to remain in Mars orbit for at least 50 years.

Experiment Summary

Television experiment (surface)

Mars can be subdivided into at least 4 major geological provinces. First is the Nix Olympica – Tharsis volcanic provinc province. Second is the Ophir-Eos equatorial plateau region with faults and rifts. A third includes cratered and smooth terrains, perhaps more ancient than the first two types, found in both northern and southern hemispheres. Large circular basins (Argyre I and Hellas) resemble impact basins on the Moon. Fourth is the south polar cratered terrain blanketed by glacial sediment layers up to 100 metres thick. Similar deposits appear in the north polar region. If large quantities of water exist on Mars, they are undoubtedly locked in the permanent polar caps.

TV Experiment (atmosphere)

After the global dust storm subsided, much of Mars above 45 deg. north was found to be covered by a north polar hood of variable clouds. They appeared to have a general west-to-east flow pattern, with some systems resembling small cyclones. Clouds believed to contain water-ice were observed elsewhere, particularly over large volcanoes. Several localized dust storms were often seen after the global storm cleared. Dust clouds appeared highly convective, probably due to vertical air motion generated by absorption of solar radiation by the dusty atmosphere.

Ultraviolet Spectrometer Experiment

Ozone was detected over both Martian polar regions and at latitudes south of 50 deg. south and north of 45 deg. north. The amount of ozone was less than 1% that present in Earth's atmosphere.

The UVS instrument, by making 30,000 individual measurements of relative surface brightness, produced a preliminary topographical map of Mars. Two areas showed very abrupt elevation changes, one being the canyon area in the Tharsis region, the other the volcanic belt.

Infrared Interferometer Spectrometer Experiment

Mars's North Pole is much colder (about 200° F. below zero) and drier than the coldest spot on Earth, Antarctica (125°F.). Again carbon dioxide was shown to be the principal constituent of Martain polar atmosphere. During the dust storm, the dust-laden atmosphere lowered maximum surface temperatures and appeared to stabilize them. Temperatures ranged from over 40° above zero F. near the equator to below 125° below zero in polar regions. Atmospheric winds reached speeds of up to 185 km (115 miles) per hour.

Infrared Radiometer Experiment

Surface temperatures ranged from 81° above zero F. to 189° below zero. The low was found at both poles; the high in the equatorial zone. Average temperatures remained in the range indicated by Mariner 6 and 7 measurements, but there are hundreds of areas on Mars significantly warmer or cooler than the averages. The variations are attributed to differences in reflectivity, local topography, surface thermal properties, and possibly internal heat. However, no clearcut examples of internal heat – that is, active volcanoes – are apparent from the Mariner 9 IRR data.

Radio Occultation Experiment

Mars' atmospheric pressures were measured to a low of 2.8 millibars in near-equatorial regions, with a high of 8.9 and a mean surface pressure of 5 millibars in the central areas. At 65 deg. North Latitude, surface pressures ranged from 7.2 to 10.3 millibars, with the mean 8.9. Mars is more flattened at the poles, with the bulgy equatorial zone showing lowest atmospheric pressures. Pressures near the Martian poles range from 5 to 13 millibars. (Earth sea-level pressure norm: 1000 millibars).

Celestial Mechanics Experiment

Mars bulges at the equator 27.2 km (16.9 miles). Variations in Mariner 9 orbital times showed the planet to be that much out of round. However, 17.8 kilometers (11 miles) of this is attributed to Mars's own spin around its polar axis Strong Martian gravity anomalies imply large stresses at work on the planet's crust, suggesting current or recent geological activity. The celestial mechanics team conducted an experiment to test the Einstein relativity theory in September 1972. Analysis of the data is continuing.

SATELLITE DIGEST – 57

A monthly listing of all known artificial satellites and spacecraft, compiled by Geoffrey Falworth. Information is based on that supplied by the Space Department of the Royal Aircraft Establishment, Farnborough, NASA, Satellite News and BIS sources. For information on the derivation of orbital parameters, abbreviations, etc. see July 1972 issue, page 262.

Continued from March issue, page 116.

Name, designation and catalogue number	Launch date, lifetime and descent date	Shape and weight (kg)	Size (m)	Perigee height (km)	Apogee height (km)	Orbital inclination (deg.)	Nodal period (min)	Launch centre, launch vehicle and payload/launch origin
1972-76A 6212	1972 Oct 2.84 15 years	Cylinder 207.75	7.50 long 2.90 dia	731	749	98.44	99.64	WTR Atlas Burner 2 DoD/USAF
1972-76B 6217	1972 Oct 2.84 100 years	12-sided cylinder + 4 booms 725.76	3.25 long 3.05 dia	732	753	98.45	99.69	WTR Atlas Burner 2 DoD/USAF
Cosmos 522 1972-77A 6219	1972 Oct 4.50 12.78 days (R) 1972 Oct 17.28	Sphere-cylinder 4000?	5 long? 2.44 dia	206 178	316 368	72.84 72.84	89.74 89.99	Plesetsk USSR/USSR (1)
1972-77C 6238	1972 Oct 4.50 19.51 days 1972 Oct 24.01	Sphere?	2 dia?	180	370	72.82	90.03	Plesetsk USSR/USSR (2)
Cosmos 523 1972-78A 6222	1972 Oct 5.48 4 months	Ellipsoid 400?	1.8 long? 1.2 dia?	272	481	71.03	92.09	Plesetsk Cosmos USSR/USSR
1972-79A 6227	1972 Oct 10.75 90 days (R) 1973 Jan 8	Cylinder-cone + boom 10250	15.25 long 3.55 dia	160 164 159 168	281 267 268 264	96.47 96.46 96.4 96.4	88.93 88.84 88.7 88.7	WTR SLC 4-East Titan 3D DoD/USAF (3)
Cosmos 524 1972-80A 6229	1972 Oct 11.50 5 months	Ellipsoid 400?	1.8 long? 1.2 dia?	267	512	70.99	92.33	Plesetsk Cosmos USSR/USSR
Molniya 1W 1972-81A 6231	1972 Oct 14.26 5 years?	Cylinder-cone + 6 panels + 2 antennae 1000?	3.4 long 1.6 dia	226 480 636	481 39300 39722	65.41 65.3 65.30	91.61 706.18 717.81	Plesetsk USSR/USSR (4)
Noaa 2 1972-82A 6235	1972 Oct 15.72 10000 years	Rectangular box + 3 panels 309.36	1.02 long 1.24 dia 1.02 high	1451	1458	101.77	115.01	WTR SLC 2-West Delta NOAA/NASA (5)
Oscar 6 1972-82B 6236	1972 Oct 15.72 10000 years	Rectangular box 15.88	0.43 long 0.31 dia 0.15 high	1450	1459	101.76	115.01	WTR SLC 2-West Delta RASC/NASA (6)
Cosmos 525 1972-83A 6248	1972 Oct 18.50 10.71 days (R) 1972 Oct 29.21	Sphere-cylinder 4000?	5 long? 2.44 dia	207	269	65.39	89.25	Plesetsk USSR/USSR
1972-83C 6258	1972 Oct 18.50 14 days 1972 Nov 1	Sphere?	2 dia?	192	260	65.38	89.01	Plesetsk USSR/USSR (7)
Cosmos 526 1972-84A 6254	1972 Oct 25.45 7 months	Ellipsoid 400?	1.8 long? 1.2 dia?	173	486	70.96	92.15	Plesetsk Cosmos USSR/USSR
Meteor 13 1972-85A 6256	1972 Oct 26.92 500 years	Cylinder + 2 panels + antenna	5 long? 1.5 dia?	867	891	81.27	102.57	Plesetsk Vostok USSR/USSR (8)
Cosmos 527 1972-86A 6260	1972 Oct 31.57 12.7 days (R) 1972 Nov 13.3	Sphere-cylinder 4000?	5 long? 2.44 dia	207 178	306 284	65.37 65.40	89.62 89.11	Plesetsk USSR/USSR (9)
1972-86D 6280	1972 Oct 31.57 15.30 days 1972 Nov 15.87	Sphere?	2 dia?	181	323	65.43	89.53	Plesetsk USSR/USSR (10)

Supplementary Notes:
(1) Orbital data at 1972 Oct 6.4 and Oct 15.3.
(2) Capsule ejected from 1972-77A at 1972 Oct 16.
(3) Orbital data at 1972 Oct 11.5, Oct 21.5, Nov 1.0 and Dec 1.0.
(4) 24th communications satellite in Orbita network. Orbital data at 1972 Oct 14.4, Oct 16.0 and Nov 2.0.
(5) ITOS D, 4th Improved Tiros Operational Satellite, 3rd operational Itos spacecraft, 3rd meteorological satellite launched by NASA on behalf of NOAA's National Environmental Satellite Service and 2nd Noaa spacecraft to attain orbit provides global meteorological coverage of Earth's atmosphere and oceans twice each day using onboard non-photographic systems, acquires global dayside and nightside cloud cover data at infrared wavelengths for later ground-commanded transmission to Earth stations, obtains Earth heat balance data and measures solar proton flux at orbital altitudes. Power supplies of 250 watts average are maintained during dayside transits by 10000 negative-on-positive solar cells mounted on three 1.65-metres long, 0.92-metre diameter constantly solar-oriented panels deployed from one side of Noaa 2 after orbital insertion while a solar cell-recharged onboard battery system provides power during Earth nightside transits and when onboard power requirements exceed solar panel capability. Spacecraft attitude control systems, utilising a digital solar aspect sensor used during initial orientation manoeuvres after orbital insertion, 2 pitch horizon sensors and 2 roll horizon sensors viewing Earth through a scanning mirror mounted on the spacecraft's circular momentum flywheel platform, drive motors, 2 momentum coils and associated electronics maintains Noaa 2's meteorological sensors constantly Earth-oriented. A quarter-orbit magnetic attitude control coil positions the spacecraft's pitch spin axis perpendicular to the orbital plane, a magnetic bias control coil reduces residual magnetic dipole moment and retains sufficient dipole moment to precess Noaa 2 approximately 1° per day for nominal Sun-synchronisation, and a pitch control loop utilising 2 magnetic field-establishing devices interacting with Earth's magnetic field produces satellite torque-produced precession. Noaa 2's antenna systems include a single command and beacon whip antenna receiving ground commands and transmitting beacon and engineering telemetry at 136.770 MHz at 250 mw, 2 real-time telemetry antennae for selectable telemetry transmissions at 137.500 MHz at 5 w and 137.620 MHz at 5 w consisting of 2 half-wave dipole antennae mounted at Noaa 2's centre solar panel extremity, and a crossed-dipole S-band antenna for weather data transmissions at 1697.500 MHz at 5 w. Multilayers of foil insulation for thermal control cover Noaa 2's exteriors while goemetrically-variable absorption surfaces on the spacecraft's space-oriented surface, variable emittance surfaces and thermally-operated bimetallic louvres on the sensor system electronics panel and a fixed radiator on the spacecraft's Earth-oriented baseplate maintain internal temperatures within nominal limits. Noaa 2's two onboard, ground-commanded, dual-channel scanning radiometers measure Earth's reflected visible-wavelength radiation between 0.52 and 0.73 micron with a 3.7 km resolution during dayside transits and Earth's emitted infrared-wavelength radiation between 10.5 and 12.5 microns with a 7.4 km resolution during dayside and nightside transits to determine cloud, ground and sea-surface temperatures. Full-scanning between horizons perpendicular to Noaa 2's orbital plane, each radiometer, situated on the spacecraft to provide maximum Sun shielding and unobstructed 150°-wide scans view Earth through a mirror continuously rotating at 48 rpm inclined 45° to the spacecraft's velocity vector. Noaa 2's two very high resolution radiometers measure Earth's reflected radiation between 10.5 and 12.5 microns during dayside and nightside transits to determine cloud, ground and sea-surface temperatures; operating in constant direct-readout mode with a resolution of 0.93 km, limited data being stored for selected Earth areas for later transmission, data is transmitted through Noaa 2's crossed-dipole antenna to NOAA stations at Gilmore Creek, Wallops Station and Redwood City. Data from Noaa 2's scanning radiometer and very high resolution radiometer is utilised in determinations of sea surface temperatures in cloud-free areas producing daily global sea surface temperature analyses for use in weather and maritime environment forecast services and in studies of sea surface temperature patterns indicating location and detail of ocean surface currents. Very high resolution radiometer infrared data is utilised in high resolution sea surface temperature analyses for selected areas of special interest to fishing industries, pollution control by monitoring bay and estuary water circulation and movement and studies of ocean conditions while Noaa 2's infrared observations of ocean, lake and rive ice are used in studies of navigation hazards and increased reliability assessments of flood potentials in remote areas. Noaa 2's vertical temperature profiie radiometer measures infrared radiation emitted from 6 measured atmospheric levels and Earth's surface in cloud-free areas and upper cloud layers in calculations of Earth's atmospheric vertical temperature distribution, altitudes of specific atmospheric pressure levels and total moisture content of subsatellite atmosphere. Providing global coverage, radiometer, mounted in Noaa 2's Earth-oriented instrumentation baseplate, scans spacecraft's subsatellite track in 23-step scans covering 59.25 km square areas in each step with a total area of 1365 km long and 59.25 km wide during each scan with an accuracy of 0.5% maintained by internal calibration system, data being transmitted to NOAA's Command and Data Aquisition stations and relayed to National Environmental Satellite Service for central analysis and processing. Noaa 2's solar proton monitor, consisting of a solar proton sensor and associated electronics, measures energetic protons in the 10-, 30-, and 60-MeV range and energetic electrons in the 100- to 750-KeV range at orbital altitudes for correlation with ground-based and other satellite data, tape-recorded Noaa 2 data being transmitted to NOAA telemetry stations, relayed to National Environmental Satellite Service for processing and subsequently transmitted to NOAA's Space Environment Laboratory at Boulder, Colorado for use in solar storm warnings.
(6) AO C, Amsat Oscar C, 6th Orbiting Satellite Carrying Amateur Radio, acts as an amateur communications satellite for multi-access communications experiment, provides instructional programmes in schools by utilising the spacecraft as an educational aid and provides communications link in the amateur waveband to remote geographical areas. Oscar 6, first Radio Amateur Satellite Corporation communication satellite, 3rd orbiting amateur radio translator, first amateur satellite to utilise newly-allocated transmission frequencies between 435 MHz and 438 MHz and first communications satellite to employ 10-metre waveband downlink, uses negative-on-positive silicon solar cells mounted on 6 solar panels covering over half the spacecraft's exterior surface recharging an onboard 18-cell, 6 amp-hour nickel cadmium 24-volt battery yielding an average orbital power output of 3.5 watts. Spacecraft exterior structure thermal control utilising vapour deposited chromium coating on kapton maintains spacecraft structure temperatures at about 15°C. Oscar 6 uses passive magnetic attitude stabilisation along the spacecraft's longest axis with an internally-mounted, 0.20 metre long, 50000 pole-cm magnet, while initial inherent satellite rotation following orbital injection action is mullified by 12 internally-mounted, 30.50-cm long permalloy rods. Spacecraft 24-channel telemetry is transmitted sequentially in Morse code at 10 or 20 words per minute between 29.45 MHz and 29.55 MHz during normal operations and between 29.38 MHz and 29.62 MHz for extended non-inverting passband operation at between 1 and 1.3 w through metal strip antennae deployed from opposite sides of Oscar 6's rectangular structure, while onboard beacon transmits at 29.45 MHz at 200mw and at 435.10 MHz at 300 mw through pianowire-fabricated quarterwave monopole antennae extending from Oscar 6's end faces. Onboard linear-frequency translator receives single sideband and CW uplink transmissions between 145.90 MHz and 146.00 MHz for subsequent relay to amateur receivers between 29.45 MHz and 29.55 MHz; repeater can also handle AM, FM, single sideband TV and RTTY signals at greatly-reduced efficiency due to repeater power being constantly required during each user's transmissions. Repeater also contains a 29.45-MHz beacon oscillator keyed to the spacecraft's Morse code telemetry encoder or the codestore message storage unit both of which are selected alternately at 14- to 15-minute intervals by an onboard clock timer. Onboard command receiver uses a 21-function pulse-command system capable of activating and deactivating the spacecraft's onboard 2-metre and 10-metre waveband repeater, 435-MHz beacon transmitter, telemetry transmitter, codestore 896-bit digital

shift-register message storage unit capable of being loaded from specially-equipped amateur ground stations and repeatedly playing back until modified to ground receivers 18-word Morse code and 22-word teletype messages principally incorporating Oscar 6 orbital information in Morse code transmitted to the spacecraft, and selection of high- or low-speed Morse code telemetry rate. Spacecraft status telemetry transmitted to ground stations includes individual solar cell performance and temperatures, electronics and battery voltages, onboard battery and baseplate temperatures, transponder and beacon transmitter power output, calibration telemetry and a spare channel. Following launch, Oscar 6 was ejected from the Delta second stage, used to launch Noaa 2 (1972-82A) and preliminary telemetry indicated that all onboard systems were operating nominally.

(7) Capsule ejected from 1972-83A at 1972 Oct 26.
(8) 19th operational Soviet meteorological satellite maintains global satellite TV observational capability of Earth's weather, cloud cover, ice and snow fields and thermal emissions of Earth's dayside and nightside surface and atmosphere. Constantly solar-oriented solar cell array panels supply power and gravity gradient stabilisation systems maintain attitude control.
(9) Orbital data at 1972 Oct 31.8 and Nov 2.3
(10) Capsule ejected from 1972-86A at 1972 Nov 12.

Decays:
Cosmos 498, 1972-50A, decayed 1972 Nov 25.66, lifetime 143.26 days.

SOCIETY NEWS

24th IAF (1973) Congress

Baku, on the banks of the Caspian Sea, will be the site of the 24th IAF Congress, from 8-15 Oct. 1973. The host organisation will be the Commision on Exploration and Use of Outer Space of the USSR Academy of Sciences.

The theme of the Congress will be *'Space Activity: Impact on Science and Technology'*. A tentative outline of the programme includes an Invited Lecture and a forum session on this theme, plus a meeting on the use of space to solve Earth problems which will bring together specialists in astronautics and representatives of developing countries. Technical sessions on advances in space engineering and research as well as sessions on educational aspects and youth activities will appear in the programme,as in former years.

The International Academy of Astronautics is preparing several symposia and other scientific meetings to be organised within the framework of the Congress. Among them is the first discussion panel on a Martian International Laboratory.

The International Institute of Space Law will hold its 16th annual Colloquium at the same time.

A complete list of sessions is as follows:

Specialist Sessions
(a) Scientific Spacecraft Systems
(b) Space Stations (including manufacturing in space)
(c) Astrodynamics (Natural Motion, Motion around Centre of Mass and Optimization)
(d) Fluid Mechanics Aspects of Space Flight
(e) Space Transportation Problems (Earth to Orbit and Orbit to Orbit.
(f) Space Structure Technology
(g) Propulsion
(h) Space Systems to Solve Earth's Problems (Observations of the Earth and its Environment, Communications, Navigation and Space Power – including all aspects of Communications, Position Determination, Navigation, Traffic Control, Space Power and Radiowave Propagation from Space)
(i) Bioastronautics (i.e. Space Medicine, Life Support Systems and Equipment and Technology Applications)

Education and Youth Sessions
(a) Impact of Space on Science and Technology Education
(b) Safety in Youth Rocket Experiments
(c) 3rd IAF Student Conference

Symposia of the International Academy of Astronautics
(a) 1st Martian International Laboratory (MIL) (Discussion Panel)
(b) 3rd International Symposium on Cost Reduction in Space Operations (i.e. Low Cost Concepts in Design and Manufacturing and Low Cost Concepts in Operations and Management)
(c) 6th International Space Rescue and Safety Symposium
(d) 7th International History of Astronautics Symposium (Contributions to the Historical Literature on Research pertaining to the Development of Astronautics initiated before 1953)
(e) 2nd International Review Meeting on Communication with Extra-Terrestrial Intelligence (CETI)
(f) Orbital International Laboratory (Discussion Panel)
(g) 1st International Symposium on the Effects of Relativity in Present-Day Space Travel

Colloquium of the International Institute of Space Law

Acceptance of papers for presentation at the Congress does not imply acceptance for publication, since the Proceedings will appear in a single volume of selected papers of general interest or survey papers. Authors accepted will be given more complete information in due course.

CORRESPONDENCE

'Down with Technology!'
Sir, Many ecologists now favour the idea of a zero – growth economy. If this view is accepted, it could greatly limit the development of space flight. If the world economy is held down to its present size, mankind may not be able to afford extensive interplanetary development. In a zero-growth economy interstellar space flight would be impossible since one starship would probably use as much energy as the present world economy does.

Therefore, the BIS should pay considerable attention to social trends that may aid or hamper space exploration. *Spaceflight* should have some articles about long range social and political trends that are influencing the future of space flight. The greatest barriers to space flight are political, not technological. For example, in the United States, there is a growing hostility to technology which has hurt the NASA space programme [1]. Also, only a minority of US college and university students welcome technological improvements [2]. These various changes should be studied by the BIS.

NICKOLAUS E. LEGGETT

1. Dr. James C. Fletcher, NASA Administrator, speech to National Association of Broadcasters *NASA Activities*, **3**, 5, May 15 1972, U.S. Government Printing Office, Washington, D.C., p.92.
2. Daniel Yankelovich 'The Changing Values on Campus', Washington Square Press, New York, pp. 11 and 42,1972.

Space Promotion
Sir, During the past 18 months I have delivered highly successful spaceflight presentations to numerous schools, societies and other interested organisations including an angling club (!), geographical and engineering associations, camera clubs and rotary clubs. The audiences have ranged from contented fishermen, through enthusiastic students to highly qualified engineers. Attendances have ranged from around 40 persons up to 350 persons. The ages have spanned from about 8 years to 85 years!

The presentations have featured an original colour slide filmshow on the NASA Apollo programme and missions, lunar rocks and minerals, the forthcoming space shuttle vehicle and futuristic planetary flights. The filmshow has been supported by original exhibits (e.g. Apollo flight plans, spacecraft models, igneous rock samples) and numerous wallcharts, photographic displays and maps. British spacecraft participation is always highlighted in the slide sequence and in supporting exhibits. All in all, my presentation is the British equivalent to NASA's Spacemobile!

On 8 November 1972, I was interviewed by BBC Radio in connection with these presentations and the resultant recording was broadcast by the local station the following morning. The estimated 'captive audience' was around ½-million persons. The interview concentrated on Project Apollo, Skylab, Space Shuttle and opportunities available to UK citizens for spaceflight participation. I was even able to 'advertise' the BIS!

I have been informed, by many of the organisations visited, that membership attendance for my presentations had increased over normal attendances and the audiences were totally enthralled and captivated by the presentation. This was evident by the fantastic number of questions launched, at myself, during question period! The response at schools was equally enthusiastic. I think I may have spoken to a number of Britain's future shuttle pilots judging by some schoolboys (and girls!) reactions! Contrary to some opinions, British public interest in spaceflight is very, very high.

I continue to deliver these presentations and any member residing within a 100-mile radius of Stoke-on-Trent who would like to receive my display for his/her local organisation, on any evening date, should contact me through the BIS, or at 24 Fifth Avenue, Kidsgrove, Stoke-on-Trent, I would be prepared to produce it on a full-time basis, throughout the UK, if there was a suitable sponsor. Aerospace companies please note!

PHILLIP J. PARKER

Interstellar Ramjet
Sir, In the September issue of *Spaceflight* (p.358), Mr. N.T. P. Lewis raises the problems of obtaining thrust reversal with the Interstellar Ramjet. Dr. A. R. Martin partially answered these problems in the same issue by suggesting that reverse thrust could be obtained by deflecting the exhaust forward at an angle to the ship's motion vector. This would, it is true, be a perfectly feasible method of obtaining reverse thrust.

However, this method would be quite unsatisfactory in practice (except in an emergency), because it depends on the ramjet system working at a high power for long periods. This would result in maintenance problems. Indeed, Dr. Martin will appreciate that the commercial jet airliners he mentions, only use deflective reverse thrust for a short period during landing. For deceleration in flight, airliners generally employ airbrakes or make use of ever-present aerodynamic drag.

I suggest a simpler mode of braking for the interstellar ramjet would be to use the immense drag of the intake as a magnetic parachute. This magnetic parachute would necessarily have to be slightly 'leaky' to allow sufficient fuel to reach the fusion reactor to keep it powered-up. The reactor would still be needed to provide power to sustain the magnetic parachute, but it would be working at a life-extending low power level. It would still produce a small residual thrust, but this would be needed for control purposes.

The magnetic parachute, having its centre of pressure forward of the ship's centre of gravity, would be dynamically unstable. A small amount of controllable thrust would be needed to keep the ship pointing in the direction of motion. Providing for this would be a simpler design problem than for deflecting the full thrust of the reactor.

A ship employing a magnetic parachute would take longer to decelerate but the saving in maintenance would more than make up for it. It would cause the ship's Chief Engineer (who, if 'Startrek' is to be believed, would be a Scotsman) less worries. Perhaps I am biassed.

Flying Officer T. J. GRANT

BIS Awards
Sir, I would like to see a list of those who have been presented with the following awards:
(a) Bronze and Gold Medals (c) Honorary Fellowship
(b) Golovine Award (d) Silver Plaques

CATHERINE D. SCOTT (National Air & Space Museum)

(Receipients of Awards by the Society are as follows):

Gold Medals

1961	Y. Gagarin	(1st man in space)
1961	W. von Braun	(Saturn rocket development)
1964	V.Tereschkova	(1st woman in space)
1970	N. Armstrong, E. Aldrin, M. Collins (1st manned Lunar landing)	

Bronze (Pioneer) Medals

1962	K. Bossart	(Atlas rocket development)
1962	F. Singer	(Scientific Satellites)
1962	A. G. Haley	(Space Law)
1970	G. W. Hoover	(Earth Satellite Concepts)
	J. P. Stapp	(Space Medicine)
	H. E. Ross	(Pioneering Space Concepts)
	E. Stuhlinger	(Advanced Propulsion)
1972	A. W. Frutkin	(International Space Co-operation)
	W. H. Stephens	(European Launcher Development)
	S. Hoffman	(Saturn rocket motor development)

Silver Plaques

1961	NASA	(Mercury Astronaut Flight Prog.)
1965	Jet Propulsion Lab.	(Ranger and Mariner Probes)
1966	USSR Academy of Sciences	(Luna 9 – 1st unmanned Lunar landing)
1968	USSR Academy of Sciences	(Venus 4 – First Probe to reach Venus)
1969	NASA	(Apollo 8 – 1st Manned circum-lunar flight)
1970	NASA	(Apollo 11 – 1st Manned Lunar landing)

Honorary Fellowship

1943	H. Oberth
1949	P. E. Cleator (Founder of the BIS)
1949	R. Esnault-Pelterie (since deceased)
1949	E. Sanger (since deceased)
1949	W. von Braun
1949	Ing. von Pirquet (since deceased)
1962	A. V. Cleaver
1962	H. Dryden (since deceased)
1962	L. R. Shepherd
1967	A. C. Clarke
1969	G. E. Mueller
1969	W. H. Pickering
1970	C. Stark Draper

Golovine Award

1967	R. C. Speiser and G. Sohl	(Cesium Electron Bombardment Ion Microthrusters)
1968	P. Bono	(Booster Recovery)
1970	G. A. Flandro	(Grand Tour concept)

Matter Transmitters

Sir, The conversion of matter into radient energy, according to the Einstein relationship: $\epsilon = mc^2$
m mass in kg, c velocity of light in meters/sec. and ϵ energy released in Joules, takes place in atomic bombs and nuclear power stations. However, in order to achieve the transmission of matter from 'A' to 'B' as postulated in the 'New Frontiers' series, a process is needed whereby matter can be converted into radiation, and then back into the same matter. It seems to me that the radiation produced will have to carry all the information about the matter from which it originated.

An analogeous policy occurs in light emission from an excited gas atom in a discharge tube. The light emitted from one atom may be focussed into another atom to produce an excited atom and this is the basis of photography. However, in the atomic nuclear the energies are much higher and excited nuclear states are known which can emit γ radiation and results in a small change in mass.

According to Plank, radiation is emitted from matter in wave pockets, so that

$$\epsilon = h\upsilon$$

where υ is the frequency of the radiation and h is Planks Constant. Plus the radiation carries with it an imprint of the matter from which it comes.

For an electron-positioned pair to be produced an energy of 0.51 mev of radiation needs to be present.

Suppose we wish to produce a proton electron pair, thus producing hydrogen gas. We would need an energy of radiation with an energy corresponding to the vast mass of the proton. A proton is a Baryon and in nuclear processes this Baryon number is conserved so an equal number of negative Baryon variables must be produced at the same time; so a proton and a neuton must be created together. The neuton can decay to a proton and an electron. Now matter contains a large number of particles which I believe to be different energy states of a few 'fundamental' particles and I feel we can believe that matter as we know it can indeed be produced from radiation of the correct phase, frequency and amplitude.

Now I believe matter (elementry particles) are standing electromagnetic waves, and although I dont know how to demonstrate this in any rigerous way I feel that they are analogous to standing waves in an unmatched waveguide.

A standing wave may be produced by two travelling waves meeting from opposite directions. So if one has a standing wave (matter) and directs upon it a travelling wave of opposite phase and will produce a travelling wave in the opposite direction. Thus from this highly inadequate reasoning, if one wanted to move matter from one place to another as radiation, radiation of the correct and very high energy, would have to be 'beamed' into the object; this would then disappear forming radiant energy moving towards the source until it meets another travelling wave of opposite phase causing the matter to become stationary again and the return of all the extended energy to the source. I feel these waves would have to be inductive but I am again apologising for my lack of mathematical ability.

Theoretically, it would seem that people could be transmitted into space without the use of rockets and without losing any energy over very large distances.

These ideas may seem strange at first sight, but information in matter in its radiating form could be stored on a photographic plate as a hologram and re-created at will. These lead to the possibility of the production of duplicates.

The energy source would have to come from the destruction of matter – and the radiation produced – by means of devices as yet unknown.

It may also be possible to calculate the hologram and thus design matter to be produced, thus enabling the creation of objects.

CHRIS STEVENS

Gravity and the Expanding Universe

Sir, I have found the series of articles stimulated by Dr. Hilton's intriguing suggestion (*Spaceflight,* Vol. 13, No. 12, pp. 477-478) that antimatter should gravitationally repel ordinary matter (koinomatter) – thereby explaining the 'Expansion of the Universe' – to be most thought-provoking. Recently in reply to Dr. Lunn's question (*Spaceflight,* Vol. 14, No. 9, p. 357) regarding possible difficulties this model may have in accounting for an 'Oscillating Universe' (such as was discussed by Alfvén), Dr. Hilton wrote: 'It is an observed fact that the Universe is expanding, and both my theory and Alfvén's explain this fact'. Indeed, for over four decades, i.e., since the observations of Slipher [1] and the work of Hubble [2], practically all cosmologists and cosmogonists have accepted these observations which indicated that the Universe is in a state of expansion. The evidence is primarily the systematic redshift of distant galaxies and quasars, which obey the 'Hubble relation', i.e., velocity of recession is proportional to the distance to the object, with the Hubble constant of proportionality usually taken as 75 to 100 kilometers/second/megaparsec. In addition, radio source count data revealed the presence of what seemed to be an overwhelming over abundance of low-luminosity, distant radio sources (1000 times as many as there should be if the Universe were not expanding).

Numerous theories and models were advanced to explain the mystery of the 'expanding Universe', involving continuous creation in Steady State systems [3] or catastrophic explosions of some primordial state ('Big Bang' models) [4, 5]. However, it is most interesting that,over the past few years, the vital evidence for Universal expansion has evaporated. *The Universe may not be expanding at all,* and if so, all of these theories have struggled to explain an illusory rather than real phenomenon. In view of the importance of this possibility, as evidenced by the observation that many astronomers, cosmologists and cosmogonists do believe that the expansion of the Universe is 'an observed fact', I wish to elaborate on this point.

At present redshift data are available for approximately 100 radio galaxies and 250 quasars and the data seem to fit a relatively well-defined Hubble relation. However, much of the evidence for 'Universal expansion' is strongly dependent upon the cosmological significance of quasar redshifts. This implies that the redshifts must be doppler in origin, and consequently, if the Hubble law holds, the quasars must be at extreme distances. However, much evidence has recently been obtained that strongly suggests that quasars are not as distant as their redshift indicate. For example, Stockton [6] established that Ton 155 and Ton 156 is a double quasar separated by 35 seconds of arc, a highly improbable discovery if quasars are randomly distributed at cosmological distances. Furthermore, Burbidge *et al* [7] demonstrated a connection between quasars and bright galaxies, also suggesting that these unusual objects may be relatively nearby. A more dramatic demonstration was produced by Halton Arp [8, 9], who obtained actual photographs of high redshift quasars connected to low redshift galaxies by luminous bridges of matter. Furthermore, Lynds [10], has shown that there are large differences between the emission and absorption - line redshifts that are intrinsic to quasars. These observations strongly indicate that quasar redshifts must have a component (possibly large) which is non-doppler in origin. Hence, the redshifts of quasars are probably not simply due to recession velocities caused by the 'expansion of the Universe'.

It is most important to recognize that there has been no independent technique for determining the distance to quasars. We simply do not know what they are or how far away they are. This point has been emphasized by recent radio-interferometric data for the quasars 3C273 and 3C279 which indicate the presence of objects which appear to be moving at up to ten times the speed of light [11, 12]. Rather than assume that there are actually observations of 'tachyonic matter' or that they invalidate the theory of Relativity, it seems far more logical to conclude that the observations simply indicate that quasars are far closer than previously believed. This, of course, greatly simplifies the problem of explaining the colossal energy source powering the quasars, because it greatly reduces the estimations of their radiant energy output.

But if the quasar redshifts cannot be trusted as valid distance indicators, what of the galaxy redshifts? They also must be viewed with some degree of caution. Arp [13,14] has also observed that small companion galaxies usually seem to have larger redshifts than the spirals associated with them, clearly indicative of non-doppler component. Indeed, Tifft [15,16] has recently provided evidence for a correlation of redshift with morphology of galaxies in the Virgo and Coma clusters. He found that the non-elliptical galaxies in these clusters generally have higher redshifts than the ellipticals. Since we perceive no reason why the non-elliptical galaxies in a cluster should be receeding from us faster than the elliptical galaxies in the same cluster, this can be interpreted as indicative of non-velocity components in the redshifts of galaxies. Tifft [16] summarizes the significance of these observations: 'Thus, whether for local or for cosmological purposes, the assumption that the Hubble velocity is equivalent to the mean redshift of a group is a questionable assumption'.

Let us now critically examine the radio source count data which has long been purported as extremely important evidence for the expansion of the Universe. Kellermann [17] has recently pointed out that 'claims for a large observed excess of weak sources have been greatly exaggerated'. Although there appeared to be 1000 times as many weak sources as would be expected in an Euclidean static Universe, it may be that only 50 strong sources have been overlooked. Kellermann concludes that 'evidence for a non-uniform spatial distribution of radio sources is inconclusive'. Indeed, it now seems that the Universe may not be in a state of expansion and the large scale distribution of galaxies and metagalaxies may be relatively uniform.

Dr. Hilton also expresses concern regarding the preponderance of koinomatter in our Solar System and galaxy: 'Where then has all the antimatter gone?' Although it is obvious that our Solar System is predominantly koinomatter, it is at present impossible to discern the nature of neighbouring stars, as the light from anti-matter stars is indistinguishable from that emitted by koinomatter stars. However, even if the entire Milky Way galaxy is ordinary matter, there is no necessity for a gravitational repulsion mechanism for ejecting antimatter stars. It is quite possible that vast clouds of matter and antimatter separate before the condensation of metagalaxies or galaxies. Alfvén [18, 19] had described a mechanism whereby these matter-antimatter clouds could separate and be kept apart by radiation pressure arising from the decay of neutral pions produced by particle-antiparticle annihilation at the cloud boundaries ('Leidenfrost' zones). Stecker [20] has recently interpreted the cosmic gamma rays above 1 MeV observed by Vette *et al.*, [21] as evidence of the presence of antimatter on a cosmological scale in the Universe.

Dr. Hilton's 'law of levity' is based upon the assumption

that the antimater should have 'negative mass' and therefore repel ordinary matter. However, antimatter is simply composed of antiparticles, which, according to quantum electrodynamics, are identical to koinomatter particles, except for opposite electrical charges and the ability to annihilate each other. The particles and their antiparticles should possess gravitational masses that are equal in magnitude and sign. Indeed, Eötvös [22] verified this principle experimentally almost three quarters of a century ago. He compared the fractional differences of the gravitational to inertial masses of three metals and found them not to exceed ½ part in 10^8. Subsequently, Schiff [23] applied the principles of renormalized quantum electrodynamics to illustrate that this experiment conclusively proves that the positron must have the same mass as the electron. (This argument is based on the fact that the Coulomb field of an atom polarizes the vacuum and produces virtual electron-positron pairs, as revealed by observations of the Lamb shift). Schiff states 'We therefore conclude that the Eötvös experiment precludes the possibility that the gravitational mass of a positron is equal to and opposite in sign from that of an electron'. Dicke [24] has repeated the Eötvös experiment to a far greater degree of precision but has reached the same results. Consequently, theoretical and experimental quantum electrodynamics support the contention that the inertial and gravitational masses of both electrons and positrons are positive and equal in magnitude. Hence, antimatter should not have 'negative mass' and should therefore attract rather than repel ordinary matter.

Dr. RICHARD B. HOOVER

REFERENCES

1. V. M. Slipher, 'Radial Velocities of Spiral Nebulae', Table published in *The Mathematical Theory of Relativity*, by A. S. Eddington, Cambridge University Press. p. 162 (1923).
2. E. Hubble, 'Effects of Redshifts on the Distribution of Nebulae', *Proc. Nat. Acad. Sci.* **22**, 621 (1936).
3. F. Hoyle, 'ANew Model of the Expanding Universe', *Mon. Not. Roy. Astron. Soc.*, **108**, pp. 372-382 (1948).
4. G. Gamow, *The Creation of the Universe*, Viking Press, N.Y. pp. 1-205 (1952).
5. G. Lemaitre, 'The Beginning of the World from the Point of View of Quantum Theory,' *Nature*, **127**, 106 (1931).
6. A. N. Stockton, 'Ton 155 and 156: A Double Quasar?', *Nature Phys. Sci.*, **238**, p. 37 (1972).
7. G. R. Burbidge, S. L. O'Dell, P. A. Strittmatter, 'Physical Associations between Quasi-Stellar Objects and Galaxies', *Astrophysics J.*, **175**, pp. 601-611 (1972).
8. H. Arp, NGC 7603, A Galaxy Connected to a Companion of Much Larger Redshift, *Astrophys. Lett.* **7**, pp. 221-224. (1971).
9. H. Arp, 'A Connection between the Spiral Galaxy NGC 4319 and the Quasi-Stellar Object Markian 205', *Astrophy. Lett.*, **9**, pp. 1-4, (1971).
10. R. Lynds, IAU Symposium No. 44, (Springer Verlag, Inc., N.Y).
11. K. I. Kellermann, B. G. Clark, D. L. Jauncey, M. H. Cohen, D. B. Schaffer, J. Broderick, B. Ronnang, E. H. Rydbeck, L. Matveyenko, I. Moiseyev, V. V. Vitkevitch, E. F. C. Copper and R. Batchelot, 'High Resolution Observations of Compact Radio Sources at 6 and 19 centimeters', *Astrophys. J.*, **169**, pp. 1-24, (1971).
12. A. R. Whitney, I. I. Shapiro, A. E. Rogers, D. S. Robertson, C. A. Knight, T. A. Clark, R. M. Goldstein, G. E. Marandino, and N. R. Vandeberg, 'Quasars Revisited: Rapid Time Variations Observed via Very-Long-Baseline Interferometry', *Science*, **123**, pp. 225-230. (1971).
13. H. Arp, NGC 7603, 'A Galaxy Connected to a Companion of Much Larger Redshift, *Astrophys.Lett.*, **7**, pp. 221-224. (1971).
14. H. Arp, 'Redshifts of Companion Galaxies', *Nature*, **225**, pp. 1033-1035, (1970).
15. W. G. Tifft, 'Rapid Evolution of Galactic Nuclei', *External Galaxies and Quasi-Stellar Objects*, IAU Symposium No. **44**, (David S. Evans Ed.). D. Reidel, Dordrecht, Holland, pp. 367-375, (1972).
16. W. G. Tifft, 'The Correlation of Redshift with Magnitude and Morphology in the Coma Cluster,' *Astrophys. J.*, **175**, pp. 613-625, (1972).
17. K. I. Kellermann, 'Radio Galaxies, Quasars, and Cosmology', *Astron. J.*, **77**, pp. 531-542, (1972).
18. H. Alfvén, 'Antimatter and the Development of the Metagalaxy', *Rev. Mod. Phys.*, **37**, p. 652, (1965).
19. H. Alfvén, '*Worlds-Antiworlds: Antimatter in Cosmology*, W. H. Freeman & Co., San Fancisco, USA.
20. F. W. Steker, D. L. Morgan, J. Bredekamp, 'Possible Evidence for the Existence of Antimatter on a Cosmological Scale in the Universe, *Phys. Rev. Lett.*, **27**, pp. 1469-1472, (1971).
21. J. I. Vette, D. Gruber, J. L. Matteson, L. E. Peterson, 'A New Component of Cosmic Gamma Rays near 1 MeV Observed by the ERS-18, *Astrophys., J.* **160**, L161, (1970).
22. L. I. Schiff, 'Sign of the Gravitational Mass of a Positron', *Phys. Rev. Lett.*, **1**, pp. 254-255, (1958).
24. R. H. Dicke, 'Principle of Equivalence and the Weak Interactions', *Rev. Mod. Phys.*, **29**, pp. 355-362, (1957).

(Dr. Hilton replies:

I am glad to see the interest taken by Dr. Richard B. Hoover in my theory that the expanding Universe is due to a gravitational repulsion between matter and antimatter.

He also raises the matter of a Universe of oscillating size. In general it would appear to me that we are either witnessing an oscillation, which could be underdamped, constant amplitude, damped, critically damped, or more than critically damped, or else a straightforward divergence from an initial condition.

To distinguish between these six possibilities we should need to make observations near the Earth over a period of time of at least 10^9 years. The alternative is to peer into deep space to distances greater than 10^9 light years. As Dr. Hoover points out, the difficulty then is to know the changes in velocity of light, absolute frequency of a spectral line, etc., over such a long period of time. I submit that measurement has not yet selected which of the six alternatives is preferred by Nature, and possibly it never will).

Orange Soil on the Moon

Sir, I have a comment to make about the recent discovery of red and orange soils on the Moon. It was suggested that the 'Shorty' crater was probably of volcanic origin. However, some people maintained that it was possible that a comet hit the Moon at Taurus-Littrow forming 'Shorty'.

A comet could not possibly have created a crater as small as 'Shorty', though it could have been a meteoroid of cometary origin. The similarity between the orbits of comets and those of meteor streams is not a coincidence; it has recently been suggested that meteor streams are formed by the rapid disintegration of comets by collision and the action of the solar wind. Recent work on fireballs has shown that most of them exploded on re-entry, suggesting that many fireballs are fragile of structure and possibly of cometary origin.

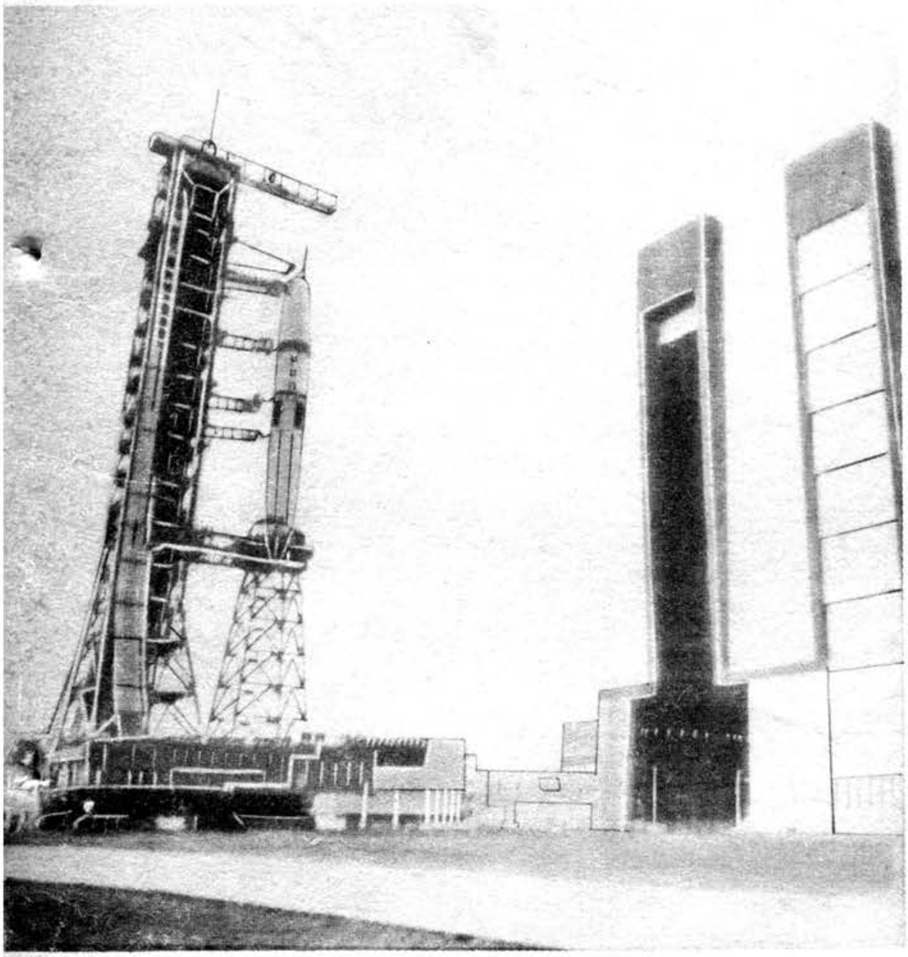
RODERICK URQUHART

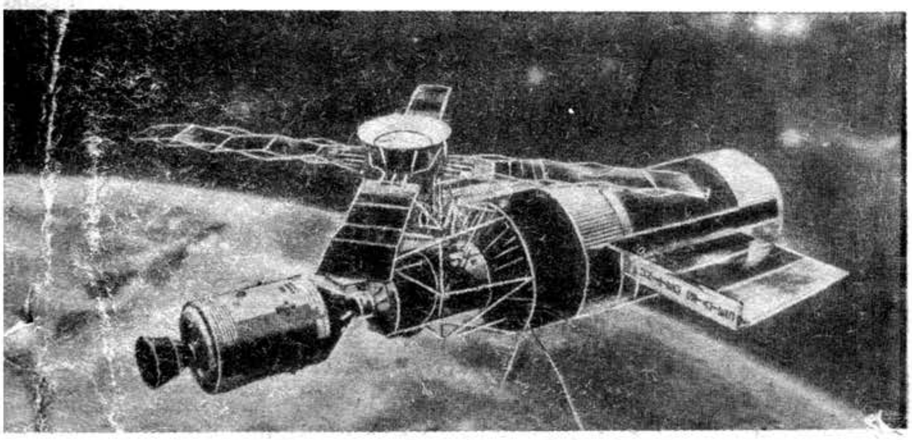
SPACEFLIGHT

88905 КОСМИЧЕСКИЕ ПОЛЕТЫ № Т-5
(спейсфлайт)
По подписке 1973 г.

Внеонередной

Volume 15 No. 5 May 1973





Published by The British Interplanetary Society

ВНИМАНИЮ ПОДПИСЧИКОВ!

В связи с задержкой поступления из-за границы журнала "Космические полеты" инд.88905 № 4 посылаем Вам последующие номера журнала.

SPACEFLIGHT

A Publication of The British Interplanetary Society

VOLUME 15 NO 5 MAY 1973 *Published 15 Apl. 1973*

Editor:
Kenneth W. Gatland, FRAS, FBIS

Assistant Editor:
L. J. Carter, ACIS, FBIS

CONTENTS

COVER

WIDENING THE SPECTRUM. Our knowledge of the Earth and the surrounding Universe should be widely expanded over the coming months as astronauts begin to work in Skylab, America's first manned space station. At Cape Kennedy final checks are being made on the 85-ton space laboratory which will lift-off unmanned from Launch Complex 39A aboard a two-stage Saturn V. Nearby, on Complex 39B, stands the Saturn IB to be launched 24 hours later with the first boarding party – astronauts Charles Conrad, Joseph Kerwin and Paul Weitz. Top picture shows the roll-out of the manned ferry (SL-2) from the Vehicle Assembly Building on 26 February. *Right,* an underview of the vehicle on its special launch platform. *Bottom,* Skylab as it will appear in orbit.

Photographs by Jacques Tiziou; artist's impression, National Aeronautics and Space Administration.

MILESTONES

Feb

13 Lunokhod 2 examines an unusual piece of material described as a one metre long plate with a smooth unpitted surface, believed to have been dug from the Moon's interior during the birth of a big crater. Vehicle is almost 5 km. from landing site and at about 300 metres higher elevation. Distance to nearest range of Taurus massif estimated to be little more than 2 km.

13 NASA's Orbiting Astronomical Observatory (OAO-2) is shut down at 10.40 p.m. E.S.T. during 22,000th orbit after 4 years of pioneering contributions to ultra-violet astronomy from space. Switch-off followed failure of high voltage system of University of Wisconsin experiment which was no longer able to acquire useful data.

15 *Novosti* reports that Venera 8 capsule used gamma spectrometer to discover radioactive elements at landing site – uranium, potassium and thorium, in percentages greater than in Earth's basalts. Density of rock at landing site was 1.4 gm/cm^3.

21 President Nixon approves Senate Joint Resolution changing name of NASA Manned Spacecraft Center in Houston to 'Lyndon B. Johnson Space Center' in honour of the late U.S. President.

22 Lunokhod 2 completes second lunar day after travelling 11,067 metres during which close study was made of transitory area between sea and continent in the southern part of Le Monnier crater. Research programme includes stereopanoramic scanning of lunar terrain, analysis of chemical and mechanical properties of soil, and measurements of magnetic fields; also corpuscular cosmic rays, solar X-rays, and lunar sky luminosity at various positions of the Sun.

Mar

11 Lunokhod 2 begins third working day at elevation of 400 metres above landing site at rim of 2 km crater believed to be 3,500 million years old. Vehicle is more than 11 km. from landing site and has received and carried out 850 different commands. Has sent more than 30 panoramic pictures to Earth which will allow maps to be drawn of Lunokhod's route, the Le Monnier crater, and southern part of the mountain range along the coast.

14 NASA confirms that the launch of Skylab at Cape Kennedy 'looks good' for 14 May with three-man crews taking off on 15 May, 8 August and 9 November.

15 Unofficially reported in Washington that China is preparing to launch a three-stage, liquid-propellent ICBM – bigger than contemporary Soviet and U.S. missiles – on test across the Himalayas and India to target centre in Indian Ocean near Zanzibar.

18 NASA announces that U.S. and Soviet scientists are to work together on the exploration of Mars and Venus. NASA to provide the Soviet Academy of Sciences with maps and photos of two Mars landing regions of Soviet interest and the available atmospheric model of Mars; Mars ephemerides from ground-based radar data for the first half of 1974; radar measurements of Mars, and results obtained on Venus during the Venus-Mercury fly-by in early 1974. Soviets to provide NASA with information on Viking landing sites obtained from Mars 2 and 3 and from future Soviet Mars missions.

THE SILVER BIRD STORY

A contribution to the History of the Development of the Aerospace Transporter – Eugen Sanger's favourite project.

By Irene Sanger-Bredt*

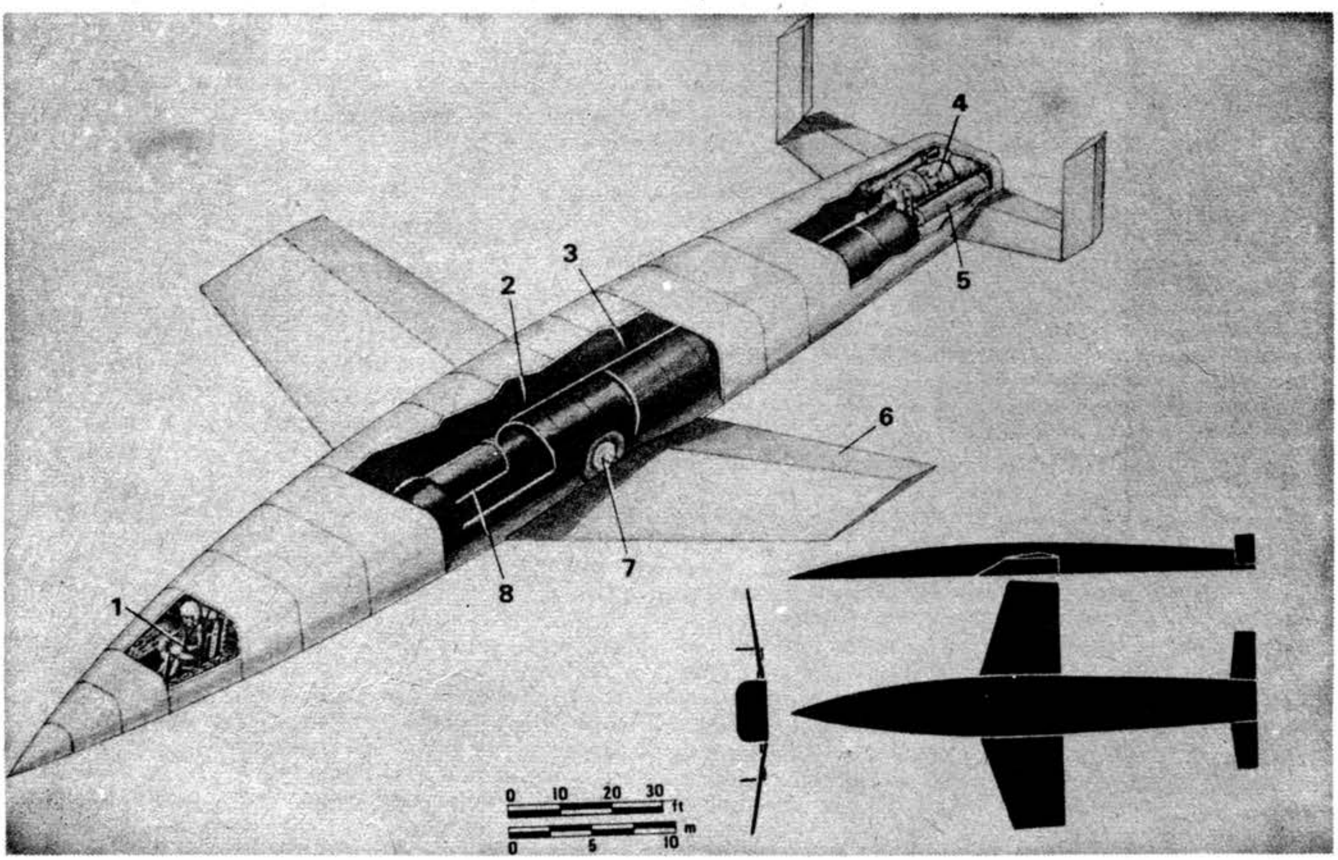
On 28 Mar. 1935, a self-willed young Viennese engineer wrote in his diary: 'Nevertheless, my silver birds will fly!' He wrote this despite having been given, two months before notice to quit his post as an assistant at the Technical College, Vienna, where he had successfully completed two years of tests with new liquid-fuelled rocket combustion chambers. Moreover, with debts in the amount of DM.2000 – made in order to finance the printing of his book, the world's first scientific teaching book on rocket flight techniques, just edited by him – he was face to face with ruin at that time.

On 23 Jan. 1964, a tired and weary man in Brussels, just 18 days before his premature death, supported for the last time his favourite project – the space-transporter. In the presence of the assembled delegates of the European aerospace industries he said:

'........An efficient, economical system of space transportation has become topical at a time when the problems of orbital rendezvous with manned space vehicles have been solved. When the first successful manned landings on the Moon have taken place, and therefore the construction of large manned permanent stations in Earth orbit and routinely supplied lunar bases, should be considered – undertakings, presumably of the next decade – then an economic system of space flight becomes essential,even indispensable......................
If these developments are not yet fully underway in the USA and possibly too in the USSR, then this is because the total intellectual and material resources of these countries are occupied with the actual pioneering efforts, especially with the race to the Moon. As soon as this strain is over, they will devote all their efforts to the next phase of practical spaceflight – the preparatory work of the American aerospace industry shows this quite clearly.
Hence, at present there exists for Europe a unique but surely a transient opportunity to become fully active both intellectually and materially, in a branch of spaceflight where the great powers have not yet gained an unassailable lead; a branch of spaceflight which promises high material profit, and may even make the USA and USSR customers of the European aerospace industries...'

Between these two dates mentioned above, and representing nearly 30 years of a man's life work, there took place the story of a technical development project named 'silver bird', in the dreams of its creator, and known by several names in the following time, such as 'flying boat', in Sanger's earliest computations and project notes; simply 'rocket plane', in the first relevant publications of its advocate in 1933; later on 'flat iron' in the jargon of the technicians at test stands and wind tunnels; camouflaged as 'rocket bomber' during the storms of the 2nd World War and finally 'space-transporter' in the language of aerospace experts at the beginning of the astronautical age.

All these names refer to a manned, recoverable vehicle for flight missions in both air and in space, especially to be used as the 1st-stage of booster rockets, or respectively, as ferry, supply and rescue equipment for use with manned space stations. Depending on the region of its flight domain, and the type of mission, the craft would be able to follow



Dr. Eugen Sanger (1905-1961), 'father' of the re-usable space transporter.

As powerful rockets ascend into space from launch centres in the United States and the Soviet Union, it is easy to forget that the space age really dawned in Europe. It was at the Peenemunde rocket establishment, on the Baltic coast of Germany, between 1938 and 1944 that man first mastered the engineering techniques of large rockets. The A.4 rocket and advanced projects such as the A.9/A.10 were springboards to the launcher development that put satellites into orbit and men on the Moon. Even the space shuttle can be said to have drawn its inspiration from Europe in the pioneer work of Dr. Eugen Sanger who regarded re-usable space vehicles as fundamental to the development of astronautics. With work now beginning in America on the first re-usable launch system, we asked Dr. Irene Sanger-Bredt to relate, in her own words, the story of her late husband's dedication to this goal.

Left, Sanger-Bredt antipodal bomber project (1938-1942). Internal detail and three-view. Overall length 28 m; wing span 15 m; launch weight 100 tonnes; maximum velocity 21,880 km/hr; maximum range 23,490 km. Key: 1. Pilot's pressure cabin; 2. Oxidant tanks; 3. Fuel tanks; 4. High-pressure combustion chamber of 100 tonnes thrust; 5. Auxiliary rocket chambers; 6. Wedge-shaped wing; 7. Retracted undercarriage; 8. Free-falling bomb.

From 'Frontiers of Space' by K. W. Gatland and P. Bono, Blandford Press Ltd., London, 1969

either ballistic or aerodynamic trajectories, and should combine the characteristics of a powered booster rocket with those of an aerodynamic glider. The realization of such a space-transporter would eliminate a gap in contemporary astronautical development – the origin of which will be briefly examined.

Of course, it may appear rather astonishing to the unaffected observer of technical development within the past 50 years that manned spaceflight did not evolve gradually and consistently from aviation; that with the ascent into the cosmos, one renounced the benefits of an atmosphere delivering oxygen and lift as well as with the concept of recovering the hardware. Instead, men are flung into space on projectiles which consume more fuel than is absolutely essential (the high acceleration being tolerable only to a select few), and of which only a small part can be returned, rather inelegantly, to Earth, fit only for a museum.

* *Mathematician who worked with Dr. Sanger on the Antipodal Rocket Aircraft; later to become his wife.*

Would the first steps of spaceflight have been different if Hermann Oberth (the spiritual father of Western spaceflight) in his youth had not read Jules Verne's novel 'From the Earth to the Moon', with the Moon traveller setting off in a cannon ball, but if instead he had been enthusiastic about more aerodynamically inspired stories such as the Icarus legend or Bishop Godwin's journey? Was it the war which made the ballistic solution (in the shape of intercontinental missiles) appear more interesting and gave to astronautics space boosters as a cheap byproduct? Or was the realisation of the space-transporter arrested, in fact, by economic considerations concerning the high development cost of aerodynamic vehicles, and doubts about a sufficiently high operating frequency of re-usable boosters?

Sanger expressed his opinion about this in his last lecture:

'When, a quarter of a century ago, spaceflight first became technically possible, two fundamentally different directions of development existed. On the one hand was the development of the ballistic, missile-like spacecraft, essentially similar to the proposals of Tsiolkovski, Goddard, Oberth and Esnault-Pelterie; whilst on the other hand lay the aeronautical access to spaceflight, namely the further development of the classical aircraft to include spacecraft capable of cosmic flight velocities – advocated by a group of Viennese scientists, including von Hoefft, Valier and Sanger.

More exhaustive work on definitive projects very soon showed that, considering the contemporary state-of-the art, fewer problems would need solving, and with regard to the low operating frequency the transportation of defined payloads would be more economical in the ballistic mode (because the absence of wings, undercarriage, etc., gave a better payload to gross weight ratio). The high production costs of such ballistic and non reusable transporters were overshadowed by the far higher development cost and consequently the economic advantage of the latter was not fully apparent. Because ballistic spacecraft can only be used once, test flights of individual craft are not possible, resulting in a low reliability which, nevertheless, seemed tolerable in view of the projected unmanned military and civil uses. Therefore, the development of ballistic spaceflight has proceeded during the last decades. This has led to the spectacular first successes, followed by the commercial applications such as communications satellites. The ultimate aim of landing men on the Moon, which represents the end of the pioneering phase of spaceflight, already lies near the limit of technical feasibility – because of the fore-mentioned restrictions on reliability. However, in the following years, the continuing demand for large transport-volumes is likely to result from a number of tasks, such as the launch and recovery of numerous Earth-orbital scientific and commercial satellites; the construction of large, manned space stations for similar uses, and particularly as transit stations between the Earth and the Moon; the provision of these space stations with the stores necessary for their operation, exchange of crews, transport of visitors and so on; the transportation to the Moon and back of materials and men required to construct permanent lunar bases; and transportation between different earth orbiting space-stations and between these and unmanned Earth satellites for purposes of control, recovery, assistance, repair, change of orbit, etc..........'.

How did Sanger come to advocate so resolutely, and so contrary to general opinion, a solution other than a pure ballistic one, more than 40 years before the Moon landing on the early morning of 20 Jul. 1969? When, 13 days before his death, he was asked by a radio interviewer of RIAS in Berlin, how he had become involved in space research, Sanger answered:

'Contact with spaceflight occurred for the first time at Grammar School, when my physics teacher gave me as a Christmas present the novel by Kurt Lasswitz, 'On Two Planets'. I was about 16 years old. Naturally I read this novel avidly, and thereafter dreamed of doing something like this in my own life-time. I started to occupy myself seriously with spaceflight when – I think in 1924 – the first publication on the subject by Hermann Oberth came into my hands. At that time I was studying at the Technical College in Vienna. I had to pass my examination on mechanics, and had, therefore, made a particular study of this and related subjects. Then I also started to check and re-calculate in detail everything in Oberth's book, and I became convinced that here was something that one could take up seriously. From that moment onwards I devoted myself more and more to these things. I did this in spite of some difficulties, because I studied construction engineering at the Technical College, and had to change faculty towards aeronautics.'

In fact, Sanger was led to his life's work through the influence of Hermann Oberth, as were so many of the 2nd generation spaceflight engineers. However, right from the start, he kept himself independent of Oberth's concrete programme of realisation. Was this because his ideas were influenced by his studies of construction techniques (particularly those of aircraft construction) when he began to occupy himself systematically with spaceflight? How far was he influenced by the 'Viennese School' of space research, by Valier or von Hoefft? Did Sanger's dedication to systematic, and thorough study, his aversion to discontinuity of thought and unconsolidated things of any kind, play any part in choosing his way? Maybe even he himself was never quite sure about this. Maybe all 3 factors were involved in his choice. However, there is no doubt that the force of his personal character must have been primarily responsible.

The idea of beginning a flight into space, taking advantage of the atmosphere by means of aerodynamic transporters, is at least as old as the designs which use a purely ballistic method.

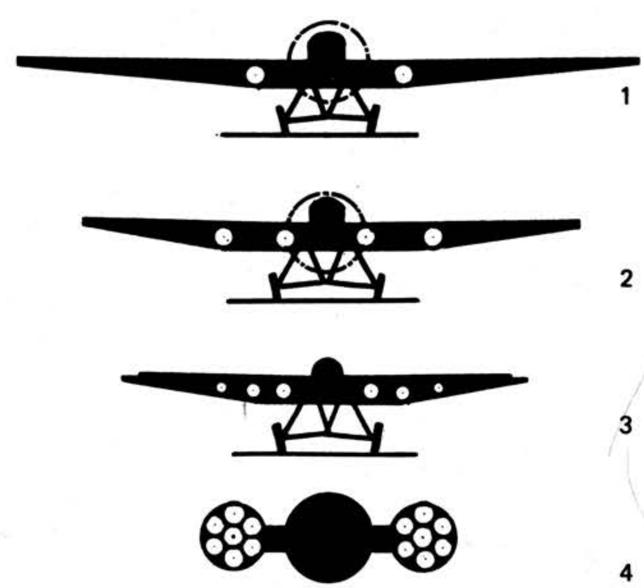
During the 19th century, ballistic rockets received considerable attention as weapons of war, e.g., with the experiments of the British Colonel Congreve and by the publications of Congreve and the French engineer, Montgery, when the French pyrotechnician, Ruggieri, demonstrated with animals, the modern techniques of parachute-landings from ballistic rockets, and a patent for an aircraft with steam jet propulsion – obtained by the Englishman, Golightly in 1841, stimulated the ideas of cartoonists. A German project of 1847, in which a rocket plane should be driven by burning nitro-cellulose, is attributed to Werner von Siemens. In 1873, the Russian General, Ivanin, proposed to power aircraft by war rockets. Towards the end of the 19th century, Ganswindt in Berlin, promulgated the idea of a space-vehicle driven by dynamic cartridges, a craft which would be carried to the upper limits of the atmosphere by a specially-designed aircraft. Further proposals for aircraft with reaction propulsion systems were known by the beginning of the 20th century, e.g. those of Christopher Antoonovitch in Petersborg (1910); Rene Lorin in Paris (1911); and Alexander Gorochoff in Moscow (1911). Auguste Piccard, the stratospheric and deep-sea research scientist, started tests in 1912 with rocket-driven model aircraft, because initially he intended to use this method to perform his researches.

It is not known if, in 1924, Sanger had already heard of any of these attempts, but he was probably aware of the work of his compatriots Max Valier and Franz Edler von Hoefft, even though he seems never to have had any personal contact with the former.

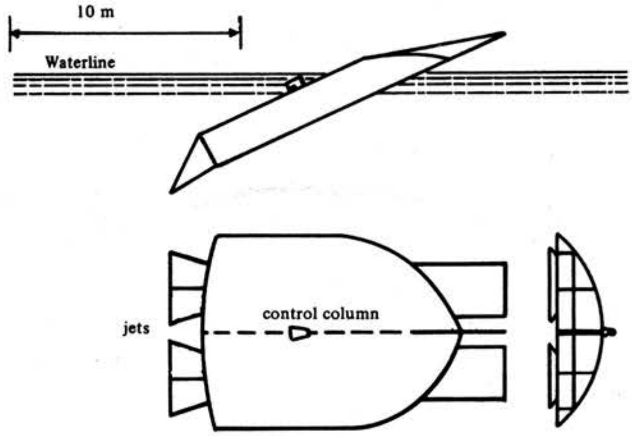
During his studies at Innsbruck in 1914, Valier had powered a model plane with firework rockets – just as Piccard had done 2 years before. However, he only began his serious study of spaceflight after war service and a study of astronomy; after he had bought Oberth's book 'By Rocket to the Planets' in Jan. 1924. Immediately afterwards he established a personal contact with Oberth which led to an extensive, still kept up correspondence, and to which soon von Hoefft and Hohmann contributed. From these letters it is clear that the views of Oberth, Valier and von Hoefft soon differed on the most suitable vehicle for spaceflight.

Oberth insisted upon a purely ballistic, multi-stage, liquid-fuelled rocket, as proposed in his book. However, Valier resolutely supported the idea of an aircraft with jet propulsion for the atmospheric phase of the flight. Valier mistakenly called it a rocket-plane, not making the distinction between turbojet and rocket propulsion. He commented in 1925:

'Consider my idea of developing the spaceship from the Junkers aircraft. I imagine such an aircraft initially provided with Blicharski's wing propeller and completely



Valier concept of a rocket aircraft developed from Junkers G23. (1927). (1) Two side engines are replaced by rocket motors. (2) Four rocket motors; smaller wing-span. (3) Six rocket motors with even smaller wings and pressurised cabins. (4) Rocketship.



Dr. Franz von Hoeff's scheme for a rocket-powered lifting body of 30 tons weight capable of taking off and landing like a hydroplane, Upper stage was to have orbital capability (1928).

hermetically sealed, with normal air pressure inside. This would be an intermediate type between the aircraft and the spacecraft. Such vehicles would take off like aircraft, but where their engines failed to work at altitude, they would be boosted with rocket impulse. They would then follow a pure ballistic trajectory over most of their flight path, but at a re-entry altitude of 10-12 km, would assume a normal gliding. Their attainment of nearly orbital velocity should be utilised as far as possible for increasing the gliding path. Owing to their wings they would finally land just like ordinary aircraft. Moreover he writes: I cannot depart from the concept of spacecraft with wings, particularly of the 'intermediate type', the rocket airplane, which daily appears to me to have greater possibilities of realisation. A rocket plane using petrol as fuel and the oxygen of compressed air could eliminate the difficulties associated with liquid oxygen and deal with technical matter already fairly well known. I believe such a craft would reach a final speed of 14-1500 m/sec. at an altitude of 15-20 km.'

In Spring 1927, in a lecture to the Scientific Society for Aeronautics (WGL), Valier described plans for the gradual transformation of a 3-engined Junkers G 23 aircraft into a spacecraft *(left)*.

'At first the Junkers G 23 will have 2 rocket engines in the wings. If this proves successful the next intermediate type will be the rocket-plane with an auxilliary engine retained for safety. After this there will be 4, and later 6, rocket engines in the wings. When sufficient experience has been gained, the pure rocket-plane, with small wings and pressure-cabin, suitable for intercontinental flights in the stratosphere, can be built. The final stage is to develop the rocket-plane which will ascend from a launch tower, and which will be further developed into the spaceship'.

Dr. Franz von Hoefft's projects are different again from those of Oberth and Valier. He explained them during a lecture to the Association of German-Austrian Engineers in Vienna on 9 Feb. 1928:

'I contemplated every possibility, from the exhaust of compressed-air to that of ether atoms and electrons accelerated by the zero-point energy of ether or by the energy of nuclear fission, until, in 1924, I read Oberth's book, and realised the possibility of achieving the necessary cosmic velocities already by using liquid fuels now presently available.

He then proposed, on the staging principle, to join jet planes (formed as winged lifting bodies) such that the upper stage became always the residual payload of the lower one, using a vertical ascent. In this way with standardised units he combined different models for different missions. From his designs he first described a 2-stage combination RH-3, of 3 tons gross weight by means of which a camera as the proper payload could be put into orbit around the Moon, and, after taking photocraphs of the far side, complete the orbit ellipse and land by parachute on the Earth. A further carrier system RH5 *(left)* with a gross weight of 30 tons, would take off and land like a hydroplane. It was intended as a manned Earth orbiting craft, or as the upper stage of a manned multi-stage spacecraft.

But strangely, von Hoefft had apparently overlooked to include in his scheme of developments the space station demanded by his friend Guido von Pirquet. Both of them overlooked the fact that the work could not be accomplished single-handed with occasional effort, but needed a well organised effort involving billions of working hours. Nevertheless, their creative imagination and untroubled optimism provided almost all the necessary elements which had to be put together when the project was finally realised.

One year before the lecture mentioned above, von Hoefft and Sanger came into personal contact. Forty years later, von Pirquet wrote to Irene Sanger-Bredt about this encounter:

'In the year 1927, Hoefft had the idea of testing a model rocket in the wind tunnel at the Aerodynamic Institute of the Technical College in Vienna. This model was designed in detail by me based on the ideas of von Hoefft. Of course, the measurements produced satisfactory results, but had no immediately-practicable application at that time.

However, we heard that a young assistant at the Institute was ardently interested in rocket problems; and so I learned for the first time of Eugen Sanger.'

In a letter dated 2 March 1928 addressed to von Pirquet, then Secretary of the Scientific Society for High Altitude Research, Sanger said:–

'With reference to a detailed consultation with Dr. Hoefft I should like to beg the favour of accepting my application as a full member of the Scientific Society for High Altitude Research and, as far as possible, of informing me of arrangements, lectures etc., of your Society.
Especially I shall be at your disposal for the preliminary tests planned at the Aerodynamic Institute, as already discussed with Dr. Hoefft.

Yours respectfully,
cand.techn. Eugen Sanger.

The letter contains a hand-written remark by von Pirquet:

'Answered 28 Mar. (on the invitation card to the lecture by Dr. Hoefft on 4 Apr.).'

However, real co-operation between von Hoefft, von Pirquet and Sanger did not occur after all, as von Pirquet told. Apart from the fact that Sanger was very much absorbed by his studies and duties as an assistant at the College, he

probably realised quite early that the most difficult part of the realisation of spaceflight lay not in the aerodynamics of the flying body, but in its propulsion. He, therefore, devoted most of his life-work to this problem.

However, in the Silver Bird Story the report on Sanger's activities and successes in developing liquid rocket engines will be strictly excluded, because they are treated already in other proceedings.

Among documents left by Sanger were some 'life programmes', written at different periods in his life. In these he formulated the aims of each of his diverse interests and carefully noted points in the programme already reached. One of the earliest of these programmes probably originated between 1929 and 1931. Beneath the caption 'Constructions' he details the following developments:

'Stratosphere plane, aerospace boat, space station, interplanetary vehicle, interstellar vehicle'.

Below the heading 'writings main work' are:

'Stratosphere flight technique, astronautical technique, bio-technique'.

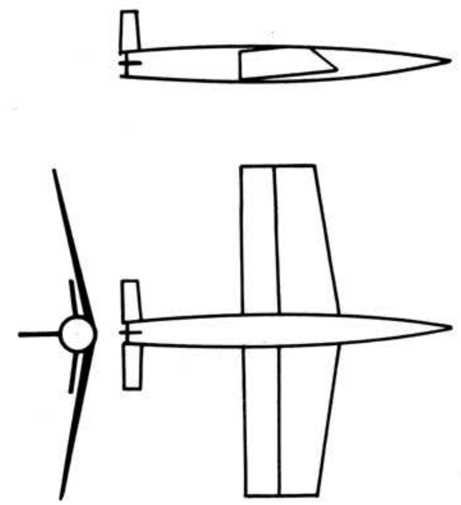
From these notes it can clearly be seen how Sanger systematically progressed both as engineer and scientist. However, he never disregarded the all over interdependence and the final aim, even when he apparently dealt only with details. Right from the beginning he believed that spaceflight was a manned enterprise and that realisation of the early stage of his project, the stratosphere plane, was only a first step on the way to realise spaceflight. But he did not want to jump over this first step, as later development did it in fact.

Amongst the notes mentioned in Sanger's early life programme was a draft on 'Rocketflight technique' whose title-page shows the additional inscription 'Dissertation for taking the degree of a doctor of technical sciences, submitted to the Technical University in Vienna by Eugen Sanger, in Summer 1928. Rocket Flight Technique (Investigation of energetics of high altitude flight with rocket planes)'.

The draft was divided into 4 parts; General considerations; Ascent; Free flight; Descent. In the introduction, Sanger writes:

'The purpose of this work is to give a systematic synopsis of all theoretical and practical knowledge to date in the field of high altitude aviation and cosmonautics. This knowledge will be presented in a practicable way appropriate to technical working and research methods, and will be supplemented by my own investigations. The investigation consists of a critical, purely theoretical, comparison of the different ways of advancing into space; it calculates the most economical and safest method (aerospace transporter – space station – space ship) and supplies a complete theory of this method. The method is arranged for use with either chemical or electric rockets, with complete, general solutions first, followed by calculations using specific data. The conquest of space with minimum energy display will proceed according to the following principles:'

1. Transport to the altitude of the space-station by means of a special aerospace-plane; further advance into space will use special space-craft.
2. Ascent of the aerospace-plane according to the principle of minimum energy expenditure.



Sanger rocket-plane (1933 concept).

3. Descent of the craft as a glider, without energy expenditure.

Already Sanger explicitly provided for the application of Einstein's theory of relativity to the phase of flight in outer space.

In his last radio interview Sanger reported the following about the fate of this draft for his doctoral dissertation, which he obviously wrote immediately after passing his 2nd state-examination on 27 Jun. 1929:

'Some years later I wanted to obtain my doctoral degree in the field of space flight. But then my good old teacher Katzmayr, with whom I studied aviation, told me: It is much more practical to prepare for your doctoral examination in a classical field – the event will then pass silently across the stage. If you try, today, to take your doctor degree in Spaceflight, you will most probably be an old man with a long beard before you have succeeded in obtaining it'.

So Sanger took his doctor degree on the 5 Jul. 1929 not on the Space-plane, but with a paper concerned with the statics of multi-sparred panelled wings.

Sanger mentioned in public his project for a semi-ballistic rocketplane for flight at a very great altitude, only at the beginning of Feb. 1933, in an essay 'On construction and performance of rocket-planes'. This essay appeared in the 'German Austrian Daily Paper', as a preliminary announcement for his textbook 'Raketenflugtechnik which appeared a month later. He proposed an aircraft of relatively conventional construction with liquid rocket-propulsion (petrol + LOX) to reach flight velocities up to 10,000 km/h (about Mach. 10) and flight altitudes between 60-70 km.

More than 28 years later on 11 Oct. 1961, Robert M. White, with the American rocket research plane NAA X-15 reached 65.9 km, the altitude considered by Sanger. The realisation of the velocity limit of Mach. 10 for rocket planes has not yet, to date, been realised, though a redesigned and improved X-15 reached Mach. 6.7 on 4 Oct. 1967.

In 1933 Sanger wrote of the shape of his planned rocketplane in detail:

'One will chose for the body a projectile-like shape, pointed in front and blunt at the back-end where the ex-

haust nozzle has to be lodged. The profile of the wings has to be as thin as possible, with sharp leading edges. The aspect ratio can then be kept low because of the negligible resistance of the wing-tips'.

Furthermore, he wrote in illustration of the estimated flight performance:

'In the first place their limit is given merely by the possible fuel load, which prevents these planes from increasing their flight velocity upto about 29,000 km per hr, when the centrifugal force of the curved trajectory becomes equal to the weight of the plane; i.e. when wings don't need anymore lift, and the plane circles the Earth continuously in free orbit without needing any driving power'.

In the preface to 'Raketenflugtechnik' we read about Sanger's project in greater detail:

'In a more limited sense the textbook deals with rocket flight carried out in the upper layers of the stratosphere with such velocity that the forces of inertia of the orbit contribute essentially to the lifting effect. This kind of rocket flight is the next fundamental step in the phase of development from the troposphere-flight established during the last 30 years. It is the first stage of space flight, the most colossal technical problem of our time.

To be this preliminary stage, and the way to the development of a space-station of the Earth is the most noble aim of rocket flight, though its realisation still lies in the future'.

Sanger's 'Rakentenflugtechnik', which is regarded today as the first real textbook on this subject in the history of rocket flight engineering, was nearly not published at all. In the course of the Summer 1932, 11 publishers refused the MSS or imposed severe financial conditions. Finally, R. Oldenbourg in Munich, who had published Oberth's Hohmann's and Valier's books, undertook to publish the book on condition that Sanger contributed 2000 DM towards the printing costs, or paid 1500 DM and brought the first 50 copies. Sanger raised the money only through great personal sacrifices by his first wife, Maria Hasslinger, and with the help of loans from his friends, especially the Baron Franz von Cornaro; and was able to repay his depts completely before 1936, after he had been engaged by the German Test Institute for Aeronautics (DVL) as technical Director of their rocket-projects.

During the Summer of 1933, in the Journal *FLUG*, Sanger outlined the development and testing of his aircraft project. One year later in a special edition of the same Journal, he calculated possible flight performance and flight trajectories assuming concrete technical data – for a body with circular conical nose and extremely thin wings, a mean drag lift-ratio of 5 and an effective exhaust velocity of 3700 m/s. For a mass ratio of G/Go = 0.16 for example, he calculated a final flight velocity at the end of the combustion period of about Mach. 13: a cruising flight velocity of Mach. 3.5 at an altitude of 40-60 km, and a range of 5000 km. He explained:

'The most important task of the constructor must be the achievement of an adequate range by severe decreases of empty weight by the most sophisticated aerodynamic shapes and by the highest engine exhaust velocity. But even with the not-unrealistic assumptions so far used, a rocket-plane with a non-stop flight range of 4000-6000 km can be confidently expected'.

During the following years, however, Sanger was not able to devote much time to his total project.

He started from the principle that first he had to develop the propulsion unit, before he could go in detail with the construction and testing of the airframe. Thus, the experiments, which he performed during his appointment as an assistant on his own responsibility in the socalled 'Bauhof' of the Institute of Construction Material Sciences served only to spur development of a regeneratively cooled liquid rocket engine. With model test chambers he realised at that time – as is well known – exhaust velocities of up to 3000 m/s.

Nevertheless, besides his practical development work on a 100 ton thrust liquid-propellent rocket-engine, Sanger still found time for theoretical studies of the space vehicle. In May 1938 his paper on the 'Gas-kinetics of very high flight velocities' appeared as a research report of the Central Office for Scientific Reports in Berlin-Adlershof (ZWB). In this study, formulae and numerical values for atmospheric forces affecting vehicles at altitudes where the atmosphere can no longer be regarded as a continuous medium, were determined for the first time. H.S. Tsien referred to this at the end of 1946 in his report 'Superaerodynamics, Mechanics of Rarefield Gases' (Journ. Aeron. Sci. X111, No. 12, p. 653, 1946); and therefore this study of Sanger set the course for subsequent American work in the field of aerodynamics of rarefield gaseous media. Sanger's report was translated into English by NASA in May 1950 and published as Technical Memorandum No. 1270. (This study, which began in Autumn 1937, also marked the start of Irene Bredt's collaboration with Eugen Sanger, which lasted over 26 years, up to his death).

In Oct. 1938, according to Sanger's directions, the construction of a steel-model (scale 1:20) of a plano-convex supersonic glider-plane was started. Its most favourable inverse gliding ratio in the subsonic wind tunnel flow with an assumed landing velocity of Mach. 0.12, and with a 5° angle of incidence was measured as 7.75. In comparison it may be mentioned that the most favourable inverse gliding ratio of the American glider M-2 was measured as 3.2, with a 12° angle of incidence, and landing velocity of Mach. 0.11. In the supersonic region and at low flight altitudes the most favourable inverse gliding ratio at Mach. 1.5 and Mach. 3.0 were calculated as 3.94 and 3.83, according to formulae by Ackert Busemann and von Karman. In the hypersonic zone (Mach. number above 5) it was calculated as 6.4 according to Newton's Theory of inelastic collisions. In comparison it may be mentioned that the best reciprocal values of gliding ratio so far obtained in the hypersonic region lie between 2-3, and 4 in the hypersonic region.

The gliding ratio of Sanger's airframe model, which were calculated for very great altitudes, i.e. assuming gaskinetic flow, proved to be considerably less favourable than those at lower altitudes but compared with the other forces acting on the craft in this region they were of little practical importance for the computation of the flight trajectories.

On the basis of these research-results Sanger applied for a patent for his proposed airframe shape, with half-ogival-shaped fuselage and wedge-shaped wing-profile. Because of its dome-shaped body profile and flat bottom, his colleagues had nicknamed it 'flat-iron'. The German Reichspatent No. 411/42 concerning 'Gliding bodies for flight velocities above Mach. 5 was given on 3 Jun. 1942 with effect from 22 Apl. 1939.

To save fuel weight, Sanger had the idea of accelerating his 'silver bird', before lift-off, to a velocity of about 500

m/s, by means of a rocket-sledge which would slide on a straight, horizontal, steel mono-rail several kilometers in length. Thus, it became necessary to obtain knowledge about the amount of friction between the sliding surface and the upper face of the rail, considering the very high sliding velocities and the subsequent high braking forces. He had to ensure of course a reliable dynamic flotation of the sliding surfaces by suitable geometry of the lubricating gap and by choice of lubricant.

For the assumed extreme operating conditions there were no reference data in the literature at that time. It was even feared that it would be impossible to control the frictional heat occurring, and the realisation of the whole catapult arrangement might become questionable in consequence. Therefore, Sanger asked his assistant Irene Bredt to collect proven values for sliding-friction and lubricating procedures from qualified experts and to study their research establishments. She visited Fottinger and Vogelpohl at the Institute for Technical Flow Research of the Technical College, Berlin, at that time the most important German research institute in this specialist field. But not even they were prepared for sliding velocities of several hundred meters per sec, and on their test-rigs (consisting of rotating elements), the highest sliding velocity obtainable was limited to a fraction of the required values, by the highest tolerable peripheral velocity, i.e. the highest practicable speed of rotation. Again Sanger had a resourceful thought. He suggested a stainless steel bullet be fired with a velocity of about 800 m/s. from a carbine rifle into the spiral introducing branch of a closed annular lubricated steel groove with a U-shaped profile. In this experiment the bullet would pass through all velocity-ranges from about 800 m/s. down to complete rest. These high velocity sliding-friction experiments were started on 2 Jun. 1939 at Trauen and demonstrated that the construction of sliding faces for velocities up to 500 m/s was possible on a carefully finished and lubricated rail. A rocket-sledge, constructed according to the plan prepared by Sanger, was used 15 years later by the American air medicine officer Dr. John P. Stapp in experiments on the effects of short, very high accelerations on the human body. These experiments in the course of which Dr. Stapp endured accelerations up to 25g met a basic condition for the feasibility of manned space flight.

A few weeks after these successful sliding-friction experiments in the testing zone at Trauen, the 2nd world war began. For the small staff of the rocket-research establishment, on the quiet Luneburg Heath, 1 Sept. 1939 meant a sudden awakening from bold, romantic dreams. Sanger with his own, shy charm and his glowing persuasive power, had succeeded in inspiring all his team and staff with great enthusiasm for himself and his plans – from the head of the testing stand, (a typical example of the Austrian high aristocracy) down to the youngest canteen-help, (a pretty North German peasant girl). This community spending together work and free time in the remote Oertze valley, rather isolated from the people and events in Germany at that time, had created their own defined dream-world where no differences of social origin were recognised. Everyone was happy to be allowed to contribute his own minute personal effort to the realisation of a dream of mankind – as for instance the driver of our service car, who earnestly hoped to pass his pilot examination and be able one day to navigate the first space-ship.

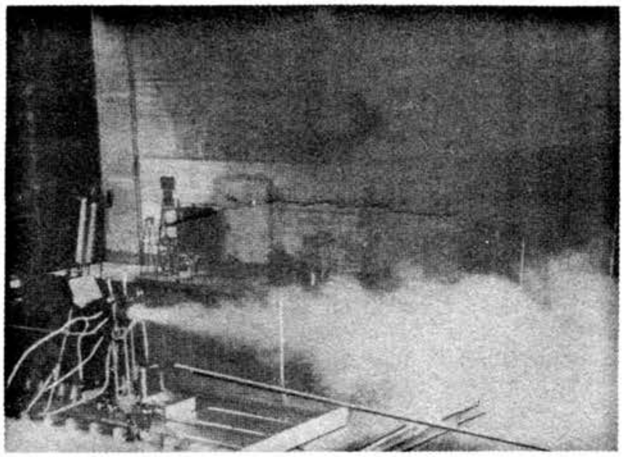
Now suddenly, there were 'priority schedules', mobilisation, and, soon, general shortage of material. The continuation of the research work and experiments at the 'Aircraft test site', which was the camouflage name for the rocket testing stands at Trauen, appeared to be in danger, for these projects were unsuitable for immediate military use. The military importance of the current work had to be proved, it was to continue, and auxiliary projects had to be worked out – projects which promised military application within a reasonable time. An example was a fighter-plane with ramjet propulsion which claimed more and more priority during the course of the war. Further, the results of the research work on Sanger's pet-project, which had just been summarised in a report with the heading 'Rocket Spaceplane', had to have a new covering if it wished to survive and had to serve a rocket-bomber project. Since that time the good old 'Flat Iron' was called 'Rabo'*, in the conversation and thoughts of the people working on it.

This 'Rabo' report subsequently had a somewhat adventurous fate. 'Enriched' by some chapters about trajectories of bombs, impact ballistics, and offense measures, the work on the original project-report could for the time being be continued. This project was mainly concerned with an Earth-orbiting, 1-stage rocket-plane with a launch weight of 100 tons (90 tons of fuel, and payload) as well as a propulsion engine for liquid oxygen combustion of highly efficient fuels in a combustion chamber at a pressure of 100 atmospheres and 100 tons thrust. The maximum flight performances of this plane assuming semi-ballistic trajectories and a specific impulse of 400 secs. were as follows:

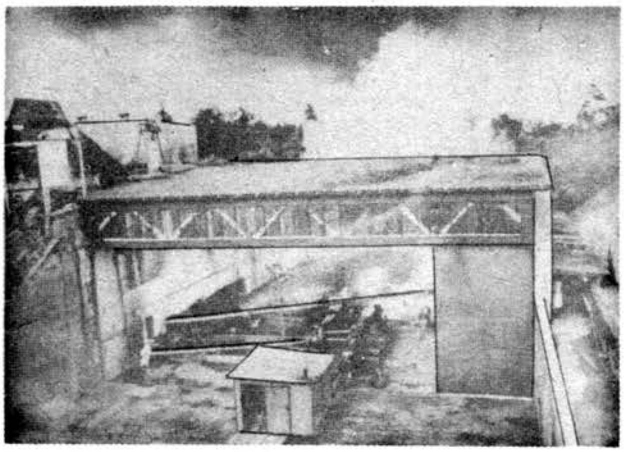
1. flight velocities at the end of the power flight phase of about 8000 m/s, corresponding to the required propulsion for reaching orbital velocity with 1 ton payload;
2. flight altitudes in the ballistic section of the flight path up to 300 km;
3. loading capacities for a transport to the antipodal point of the Earth (20,000 km) up to 8 tons;
4. flight distances up to a single Earth orbiting with a payload of 4 tons or up to 2½ orbits with 1 ton payload.

These flight performance data became possible by the application of a semi-ballistic flight technique, proposed by Sanger, where the aeroplane ricochetted from the dense layers of the atmosphere like a stone flung at a flat angle across a surface of water. In this way gliding flight-paths could be obtained which were several times the range obtained with mere aerodynamic descent.

The manuscript, with a new heading *'On a rocket propulsion for long distance bombers'* was completed in 1941, and was submitted for approval on the 3 Dec. 1941, but it by no means received the same enthusiastic approval from the relevant authorities in the State Aviation Ministry as it later on received from Eastern and Western countries abroad. On the 17 March 1942 the printing of the report was, at first, rejected outright by the Research Institute for Aeronautics (LFA). Sanger who, in private life was a most peaceloving person, was not prepared for compromise in his technical projects. Therefore, with a refusal, began for him a period of bitter argument. Because of fuel shortage on account of the war, as well as objective and personal differences between Sanger and his immediate superior in the LFA Institute, the work of himself and his team on the development of the 100 ton rocket-motor had to be stopped in Autumn 1942. However, Sanger and his closest colleagues were able to

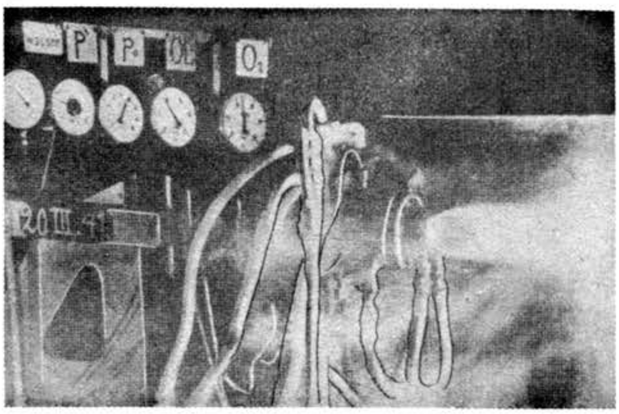


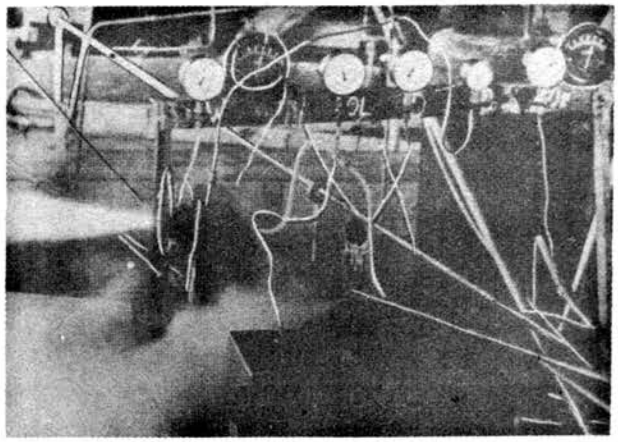
Above, Rocket motor test stand experiment, using aluminium gas-oil dispersion as fuel. White clouds of aluminium oxide form in the exhaust.



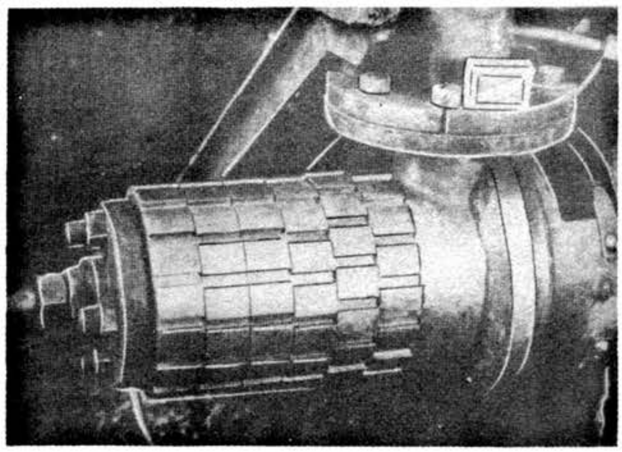
Above, General view of one-ton high-pressure combustion chamber experiment with cooling agent vaporisation for the rocket motor.

Below, Test Stand: monitoring instruments and rocket motor producing 1.1 ton thrust 100 atm, 3½ min. duration experiment.



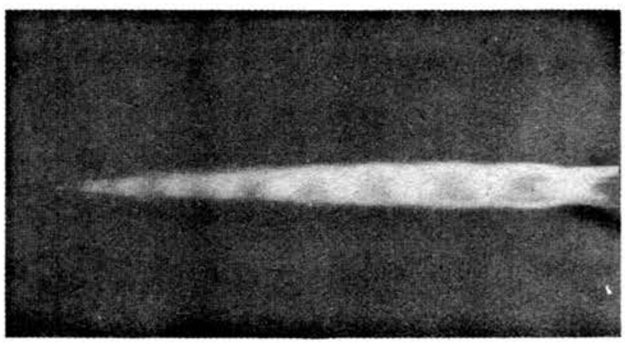


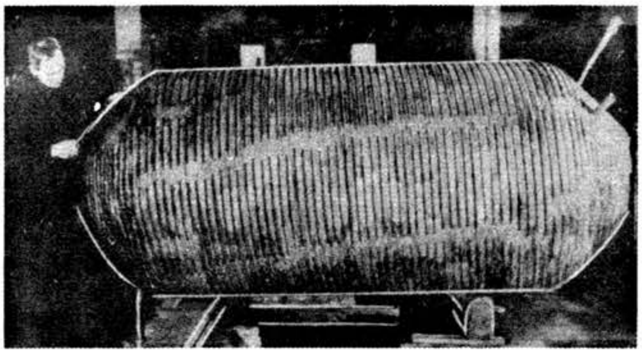
Above, Small combustion chamber and instrument panel in endurance test with cooling agent vaporisation and overheating to 400°C at 100 atm. pressure inside cooling system.



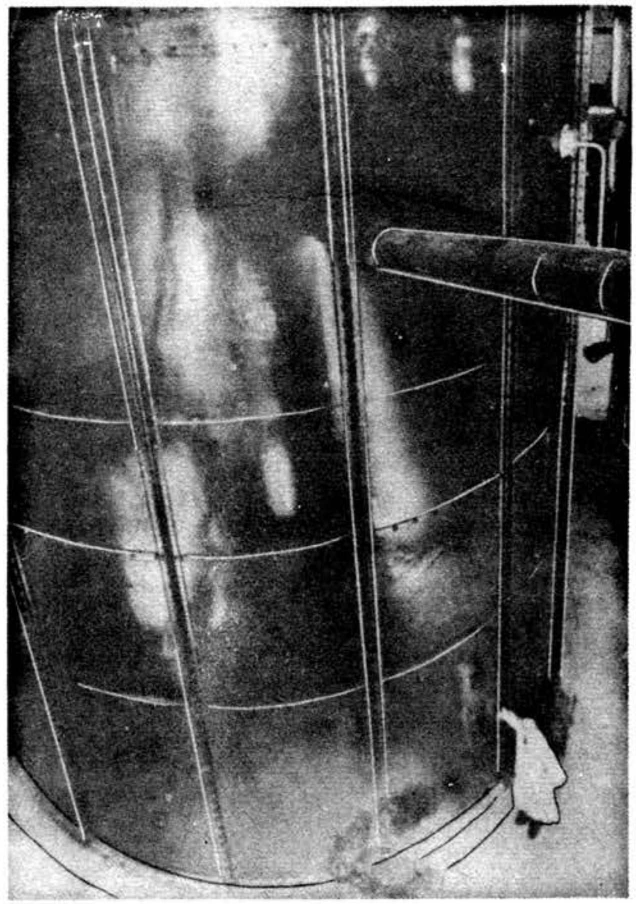
Above, Experiment using 6 stage high-pressure liquid oxygen pump with delivery of 5 kg. per sec. to 150 atm. at 15,000 rpm.

Below, Supersonic exhaust jet from rocket motor at 1.1 ton thrust.



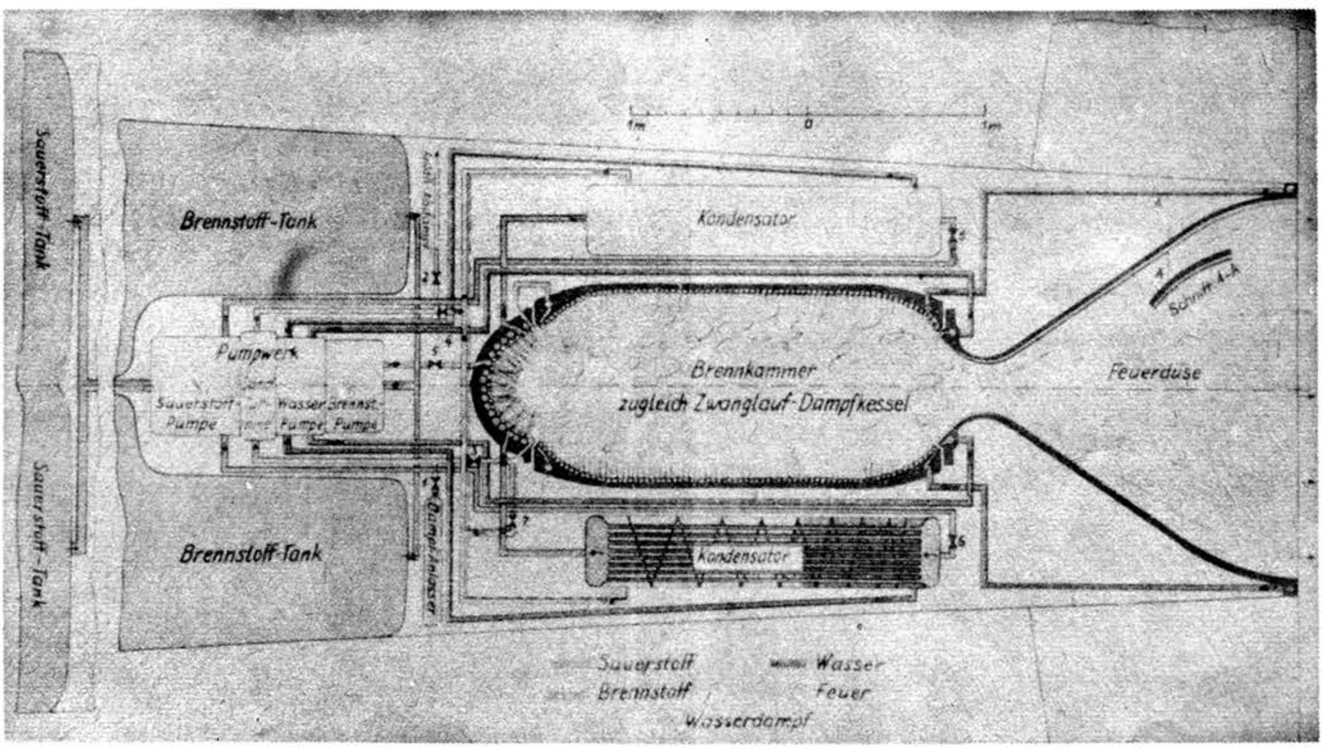


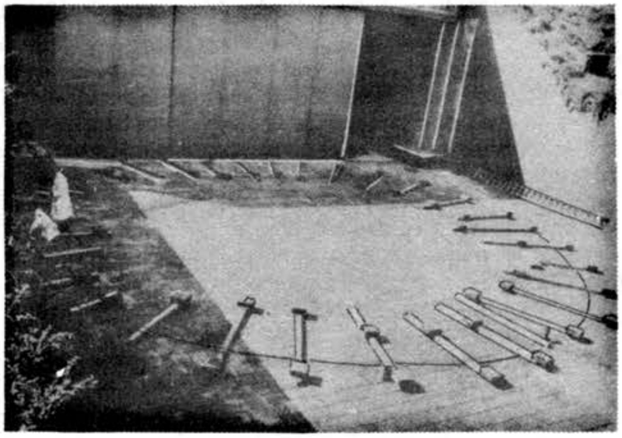
Above, Experimental cooling of the vaporisation system of 100 ton rocket and high-pressure combustion chamber.



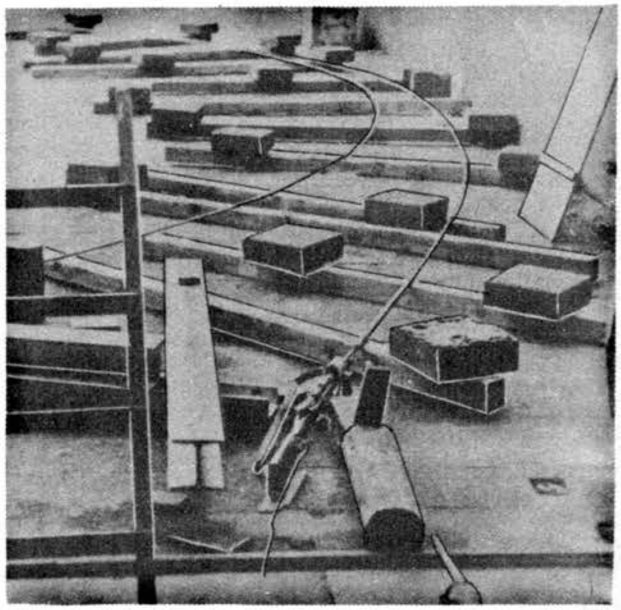
Right, Outer view of liquid oxygen container, holding 56 tons. The insulation thickness is 2.6m. Daily vaporisation loss is 140 kg.

Below, 'A rocket propulsion system for long distance bombers', by E. Sanger and I.Bredt. Deutsche Luftfahrtforschung. Information Bulletin No. 3538.





The installation consists of a military carbine and a closed circular sliding track.



The 98K carbine missile is injected at a speed of 800 m/sec. into a spiral sliding track.

continue a series of tests on ramjet propulsion at the German Research Institute for Gliding Flights (DFS) at Ainring.

Work on projects adapted to the immediate requirements of the time included development of a ramjet-flighter, an auxiliary ramjet propulsion engine for thrust increase of the Me 262 and related projects, which allowed no time for a detailed engagement with the problems of the space-transporter. However, with the support of Prof. Walter Georgii, Sanger succeeded at least in publishing the report *'On a rocket propulsion for long distance bombers'* – even though shortened to half of its original size – as UM 3538 'Secret Command Report' of the German Aviation Research. The official approval for printing reached Sanger on his 39th birthday, 22 Sep. 1944.

Events then seemed to follow in great rapidity; total war, shifting the work teams into emergency accommodations in the surrounding villages, collapse of the German Reich, occupation by Allied Forces, and operation 'Paperclip', with Sanger and Irene Bredt taken to Paris as consulting engineers of the Arsenal de l'Aeronautique.

The collaboration with French officials, engineers and workers was throughout agreeable in both technical and human relationships. In addition, Sanger and his collaborators experienced an early and generous grant of freedom of publishing. However, the strenuous reconstruction of the French aviation industry during the first years after the war naturally allowed no scope for far-reaching and expensive projects such as a satellite vehicle. Besides, the frequent changes of Government by no means encouraged continuity of current projects. For example, it happened that one evening we could convince Government representatives by a successful experiment of the suitability of a launching rocket with an alcohol-water mixture as fuel, only to be told the next morning that a new Government had cancelled all liquid-rocket projects!

So the project of the space-transporter rested in the refrigerator of World Politics.

In the meantime there were little encouragements such as collaboration on the design of the French ramjet research-plane GRIFFON or even the news of the successful first flight of the American rocket research plane Bell X-1 which brought new confidence to Sanger after years of frustration. With the resumption of international contacts, Sanger could also see, to his pleasant surprise, that his early Viennese work had not been forgotten and that he had won most of his new friends with exactly the project which had so far caused him most annoyance in his home country.

Some of the 70 distributed copies of the secret report on rocket propulsion for long distance bombers had fallen intact into the hands of the Allies, with the conquest of Berlin and Dessau. In the usual way they had been brought to the notice of the rocket research scientist and engineers in the various countries. Some of them like Ananoff, von Karman, Malina, and Stemmer, were already in contact with Sanger before the war; others, like Cleaver, Clarke, Durant, Haley, Shepherd, and Tabanera were congenial with Sanger and recognised at once in the rocket-bomber project the first phase of the realisation of space flight. Immediately after the end of the war, in most of the highly industrial countries, private and national societies for the furtherance of space flight had been formed, in which the specialists of rocket technology were of great importance.

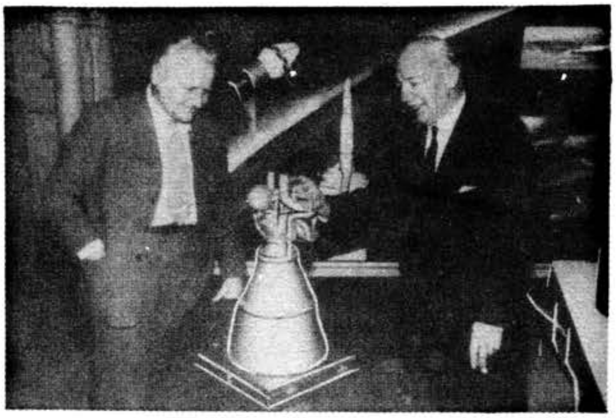
Some of these bodies met in Paris in the Autumn of 1950 and decided on the foundation of an international head organisation for the advancement of peaceful space flight. They selected Sanger as Chairman of a preliminary commission and, in Sep. 1951, as first President of the newly founded International Astronautical Federation (IAF). Already, since 1949, numerous national space societies had nominated Eugen Sanger as an honorary member.

In the meantime Sanger had been able to publish some of the chapters which had fallen victim to the shortening of

* *Rabo is an abbreviation of 'Raketen-bomber' = rocket bomber!!*

his report; such as in 1949, *'Kinematics of Spaceflight'* in INTERAVIA and 1951 *'Atlas of trajectories of rocket-planes to the spacestation and back'*, in the Research Series of the Northwest German Society for Space Research.

On 19 Apl. 1952, Lt. Gen. Dr. Walter Dornberger, the former Commander of the Research Institute for Rocket-Weapons at Peenemunde, called on Sanger in Paris, as a representative of the American Bell Aircraft Company to invite Sanger and his collaborator, who had become his wife in the meantime, to collaborate on a rocket-plane project which they hoped to develop, following their success with the research-plane X-1. In spite of the tempting prospects Sanger and his wife were unable to make up their minds to accept this offer, partly through family reasons and partly because many of Sanger's French friends on the other hand feared that he would not be happy for long in the rough, impersonal climate of American industry – especially as the receipt of a US Government order to Bell was then only something to be decided after Sanger's entry into the firm. Whether the decision to stay in Europe was right or wrong, and if by moving he could have changed anything in the destiny of the space-transporter, must remain unanswered. The friendship between Dornberger and Sanger could not, however, be tarnished by this refusal. The day in Spring 1961 when Dornberger invited him to the Bell Aerosystems Company at Buffalo to show him proudly the regeneratively cooled liquid hydrogen – liquid oxygen rocket motors with bell-shaped short nozzles, developed according to the Sanger-patents,was certainly one of the happiest days of Sanger's life.



Dr. Sanger and Dr. Walter Dornberger with a model of LO_2/LH_2 rocket engine built according to the Sanger patents by Bell Aerosystems Company.

It was obvious that Sanger, who had remained a sensible realist in spite of all his ambitious technical plans, started by degrees to worry as to how far his projects, despite their technical feasibility, might after all be realised, considering the political-economic situation. He asked himself how large working capacities could be made available in favour of a concrete technical development programme in order that its realisation was guaranteed as far as scientific and technological aspects allowed. This led, in 1951, to the study 'What are the costs of Spaceflight?', in which Sanger tried to extrapolate, from assessments gained by experience at that time, the probable costs of development of representative space projects such as the first Moonshot, an antipodal rocket plane, a manned space-station, and a manned orbital flight around Mars. A diagram from this study, subsequently extended, shows the consumption of working hours for development as a function of the necessary engine exhaust-velocity for different missions according to the technical level of development. The diagram shows, for the first time, that while these projects lie still within the capacity of great nations, they surpass by far the capabilities of single smaller nations or even private industries. Six years before the successful launch of a first artificial Earth-satellite Sanger realised that space flight even in the neighbourhood of the Earth belonged to one of the modern large scale techniques

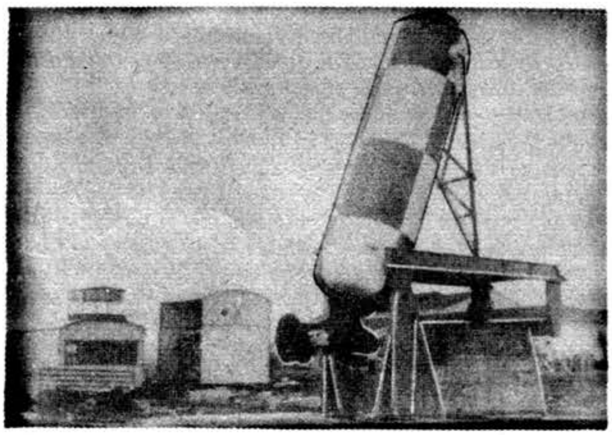
like nuclear energy engineering, data processing and cybernetics, where decisions, because of the high expenditure on development, must move more or less completely from the economic sphere of private enterprise into the region of political power.

Subsequently he tried to interest international societies in the project of the space-transporter, and decided to confine his own immediate research work to smaller, separate parts of the general project. He did so because he recognised not only the necessity of international co-operation, but also that the partners of such a community must, besides money, contribute technical 'knowhow', in order effectively to participate in the development.

His appointment in Stuttgart from Summer of 1954. with the task of building and directing an Institute for research in the interim region of aeronautics, allowed Sanger to restart again some modest practical work of his own after the restitution of German air sovereignty in 1955 and as soon as the restrictions on peaceful experimental work on aerospace problems had been removed. He concentrated on preliminary work for the development of suitable auxiliary starting equipment and main propulsion engines for the space-transporter. At first he began with the project of a ground fixed launching device with steam rocket propulsion, following this with a liquid rocket engine with air admixing to the exhaust jet according to ram jet principles. He also worked on an alternative solution for a multiple stage transporter, i.e. the project of a supersonic ramjet engine for propulsion of the first stage. Apart from this he encouraged systematic basic research into different fields which might become interesting with the further development of the whole project. He wrote in this context:

> 'Though design, construction and use of aerospace vehicles in the end form the crowning of all aerospace research, they in themselves represent,even within the scientific research,work on secondary problems, since clarification of basic problems must precede these dominant routine engineering tasks'.

Sanger recognised that the necessity for international cooperation in the development of large scale technical projects are not dictated only by economic factors, for in his paper *'Research within the interim region of Aeronautics and Astronautics'*, (1954) he explained:



Steam catapult device developed by Sanger in the mid-1950's tested by the West German Research Insitute for the Physics of Jet Propulsion at Echterdingen.

The basic idea of the International Astronautical Federation and its most noble vocation is to let space flight become an aim for *all* mankind.

The innermost motives for this aspiration might be primarily ethical or might be founded in human enthusiasm for a scientific technical problem with the fascination of space flight, which allows one to forget, our relatively insignificant daily worries beyond this immense task of the human community. But there are also a number of very sober, objective reasons for space flight to be realised only on an international basis.

One compelling reason for international co-operation of spaceflight appears clearly in space-*research*, because a single nation may have insufficient intellectual capacity to meet the wide ranging scope of scientific and technical problems involved............

If we are forced to internationalise space-*research* because of our limited intellectual capacities, then this argument applies just as much to the field of space-*technology*, because of our limited national resources i.e. our working capacity.

It has been pointed out several times that space flight with characteristic flight-velocities up to about 13 km/s, such as missions with long-distance rocket-planes, ballistic Moon rockets, space-stations and Moon orbiting satellites,still fall into the region of the military budget of the greatest nations as to their real expenses..........

Further plans, with characteristic flight-velocities above 8km/s, for the whole mission, e.g. manned landings on the Moon, circumnavigation or landings on planets, demand higher expenditure than a single nation can tolerate and are beyond any national defence budget'.

At the age of 30 years, Eugen Sanger, had, in his thoughts and diaries, fought the conflict if he, as engineer, should build his 'Silver Bird' and thereby realise the first phase of space flight, or if he, as a writer, in the novel 'Thule', should draw for his contemporaries the picture of an ideal mankind whose intellectual and cultural maturity would be equal to the plans of space flight. However, at the age of 50, he was aware that, in fact, he ought to have created both at the same time; that a rapid realisation of his technical projects assumed moral and political insight on the part of the different nations and their authoritative individual representatives which simply did not exist. Up to then he had believed as a matter of course in the reason of men and in their decency. Now, as the wish for the realisation of his technical plans forced him to come to terms with just these men,he was attacked because of his 'naivete' and was, furthermore attacked out of ignorance vis-a-vis his plans. For the first time in his life he really began to despair.

In Summer 1957 he suffered his first heart-attack. Still in his sickbed, he wrote a paper about the stage of development of missiles, unmanned supersonic flight devices and space vehicles in East and West. The news of the development of the American rocket-plane, X-15, which was to serve for research into manned high-velocity and mesosphere flights, encouraged once more his confidence.

During his recuperation at the idyllic Ostersee in Upper-Bavaria he heard, on the 4 Oct. 1957, of the first successful launch of an artificial Earth satellite, orbited by means of a multiple stage, ballistic rocket from USSR. With this event space flight had overnight become respectable. The crowd of reporters who in those early days flooded the quiet Lauterbacher Muhle, Sanger's refuge, already foreshadowed the fact that from now on pre-occupation with space flight would be-

come political pre-occupation too, and attract profiteers as light attracts the moths. Furthermore it would become an instrument of the 'cold war' between nations and last but not least a stimulus for the whole industrial technological development on Earth, and thus represent a considerable factor in economy and power.

In smaller countries, especially in Europe, there suddenly appeared the prospect of national budget funds for space research. The time which was so greatly desired by astronautic pioneers ever since, had dawned, – when nations were furthering space flight by the official representatives of science, technology and governments, including all its advantages and disadvantages. The former disregard of all space endeavours now became a passionate struggle for the best starting places, it was not by chance that the centre of gravity in the project was immediately shifted from astronautics technology towards space-research.

Already in 1958 the International Council of Scientific Unions (ICSU), in which the national Academies of the Sciences of about 40 countries were united, founded a special committee for questions of space research, COSPAR (Committee for Space Research). An 'ad hoc' committee for furthering peaceful use of space, was likewise formed in 1958 by a resolution of the UN plenary session. On the 11 Dec. 1959 this was converted into a standing UN Committee with at first 24 member states.

In the West European sphere the 'Groupe d'Etudes European pour les Recherches Spatiales', active since Jun. 1960, developed into the European Space Research Organisation (ESRO), the foundation agreement of which was signed in Paris in 1962. Parallel with these developments, in nearly all civilised states, national Space-Authorities or Committees were formed.

However, all these newly-formed organisations limited their range of work to new possibilities for space research opened up by satellites and space probes. In the technological field they concerned themselves only with the development of scientific instruments and their containers, i.e. payloads. They didn't care about the technical feasibility of sending men and equipment into space. Especially they were unconcerned about the development of carrier-rockets or even of manned space-vehicles, the eventual availability of which they took for granted.

The political doutfulness and imprudence of such an attitude was not difficult to recognise. Following a suggestion of the British Government dated 2 Sept. 1960, Australia, Belgium, Germany, France, Great Britain, Italy and the Netherlands, therefore, joined in the task of developing a European satellite-launcher. An agreement for the foundation of an European Launcher Development Organisation (ELDO) with headquarters in Paris on the 18 Sep. 1962, was signed successively by the member states and was at last ratified on the 5 May 1964 – 3 months after Sanger's death.

Although the first successes with the trials of the American X-15 rocketplane were obvious from 1959, and although one knew with reasonable certainty that in the USSR work on the development of recoverable aeroballistic carrier equipment was proceeding,especially theoretical and experimental studies concerning skip-flight, the work of ELDO concentrated on the development of a 3-stage ballistic carrier rocket of classical construction, and whose single parts were separately developed in the different member countries or modified from existing hardware.

Sanger (who attended the preliminary discussions for the foundation of ELDO in Jan. 1961 as a German delegate at the first expert conference in London) had recognised 2 essential weaknesses of this organisation:

1. When the project was started, it was already technically surpassed, e.g. the conceived ballistic carrier rocket EUROPA, could only be useful for training new working teams and organising their optimal efficiency in large-scale technical projects.
2. An international body of the character of ELDO, where political interests claim priority over technical necessities; where the different interests of the member states have to be reconciled by conference-partners with no real authority, and where no long-term commitments can be concluded; where besides all this, *technical* decisions are made by *political* functionaries; where each decision is preceded by time-consuming bureaucratic measures; and where the real experts of the technical developments at best, are only briefly heard....... such an apparatus cannot conceivably effect the realisation of true technical progress, especially if there exist competitors in its neighbourhood with less heavy organisations.

The subsequent fate of ELDO confirmed Sanger's gloomy prognosis.

He, himself,tried in the following period to act according to his perception – on the one hand by public education work, on the other by attracting those organisations who seemed to be suitable to carry on the developments. He had, so to speak, to struggle on 2 fronts; firstly for his project of an aeroballistic space-transporter and secondly against the chronic aversion to manned space flight, serving as a ferryboat between Earth and space stations, especially that of German officials.

So in 1962 and 1963 he originated (in quick succession) the following publications:

'Which gaps in the spaceflight technique could be filled by Europe'?
'Spaceflight – yesterday, today and tomorrow'
'From ballistic to aerodynamic spaceflight'.

'Now or never – Eleventh hour for European spaceflight', and last but not least a Memorandum of 21 pages dedicated to the President of the German Federal Republic in which Sanger – following an introduction into the consequences of space flight and the necessary expenditure for realisation – drew up a detailed programme of the basic research into space flight and into the organisation of space flight engineering in Germany, and indicated again the propositions presented by him concerning the formation of centres of main effort in the European aerospace industry:

1. 'Small satellite carriers and Earth satellites on the basic existing English Blue Streak, and French Veronique rockets, in the framework of the European Satellite Programme, mainly for the introduction of the European industry and research into the technique of spaceflight.
2. Manned aerodynamic Earth-Orbit-Earth-space-transporters to supplement the corresponding US developments which worked only with limited resources, and the construction of economical and reliable supersonic planes for the fastest possible air traffic and as conveyor vehicles to Earth satellites and Earth space-stations.
3. Fast manned interplanetary space vehicles based on the development of nuclear-energy rocket engines of high thrust, and of high specific impulse'.

Propositions (2) and (3), made in 1961 by Sanger, correspond exactly with the latest US official general

conception with the following key elements: Space-station, Space-shuttle, and the Nuclear Project (Rover) as it was made known by President Nixon in Sept. 1969. About a possible starting date for such a development. Sanger wrote in 1959 in a contribution 'The future of spaceflight' to the collective report of the Select Committee on Astronautics and Space Exploration, on 'The Next Ten Years in Space, 1959-1969', for the American Congress:

> 'As the first interplanetary phase of manned space flight begins – probably around 1970 – man will be entering the cosmic age. Proper space craft are unlikely to enter the atmospheres of the Earth and other planets, and will instead be moving amongst the external stations of the planets in empty, interstellar space.'

The time-table for the following phases of development, namely research, development, testing, production, and actual use between 1960 and 2000 was described by Sanger in a graph for the following spaceflight-projects': First-landing on the Moon; installation of a near Earth space-service-system (aerospace-transporter); construction of permanent Earth-orbital space-stations and Moon-stations; high efficiency nuclear propulsion-engines; installation of fast interplanetary transport system; pioneer flights in interstellar space.

Sanger gave still more details of his ideas about the future progress of space developments in a speech, on the occasion of his taking over the newly-created chair for Spaceflight Technique at the Technical University of Berlin, early in 1963:

> 'The first pioneer phase of pratical space flight will probably be terminated during the next few years with the landing of men on the Moon. With this event practical space flight in the neighbourhood of the Earth will enter into its next phase, that of great regular transportation problems, as the organisation of a hypersonic air-traffic over long distances on Earth; the building of manned space-stations circling the Earth; and the construction of fixed habitable stations on the Moon.'

The demands for large and presumably rapidly growing transport-volumes in space, expected in the next few years, arises from a number of tasks.

a) Establishment of a hypersonic air-traffic system between points on the surface of the Earth over distances from 8000-20,000 km, with flight lengths below 2 hr, that means, with the highest physically-possible velocities within the Earth's atmosphere.
b) Launch of numerous scientific and commercial satellites into the Earth orbit, and returning them after they have concluded their mission.
c) Building of large, manned space-stations in Earth orbit for scientific and economic purposes, and especially as transit stations for transporters between Earth and Moon.
d) Provision of these manned space-stations with the materials necessary for their maintenance, change of crews and transport of visitors.
e) Transport of the necessary equipment and men to the Moon and back to Earth, required for the building and continuous management of permanent Moon stations.
f) Transport between different Earth space-stations, and between these and unmanned satellites for the purposes of control, salvage, rescue work, repairs, change of orbit, etc.
g) Military and space police services.

This increase in missions and in transport volume which require a regular transportation system within the near space, introduce a whole range of new and greater demands on the spacecraft.

In the first place the average of only 50% reliability of today's ballistic space vehicles is much too low for these tasks, especially as the spacecraft during this second phase of practical astronautics, will have to carry not only their trained crews, but also passengers.......

Besides precautions for improved reliability, there is a growing demand for better economy, i.e. minimising the ton/km cost of the payload capacity of hypersonic transports on Earth respectively – the global cost of transport of 1 ton payload into orbit, or to the Moon. Besides more claims on reliability and economy this regular space-traffic demands more freedom of launching and landing facilities than current technique allows.

No ideal solution to all these numerous and ambitious new requirements from space transporters is possible in the foreseeable future, though some of them may be easier to be satisfied with aeronautical spacecraft, according to the Viennese trend, than with the prevailing ballistic transport vehicles, whereas the immense experience gained in the meantime with supersonic aeronautics and astronautics has now relieved many of the additional and difficult technical problems of these spacecraft.

Aerodynamic spacecraft will start from an airport more or less like normal aeroplanes and will fly at hypersonic speed to a very distant point on the surface of the Earth, into Earth orbit or even to the Moon. At its destination point it will carry out defined tasks, especially discharging payload transport from Earth, such as goods or passengers. Thereafter it may load new cargo, and return to the surface of the Earth, and, after a glide path, land at any airport like a customary airliner. Such missions may be repeated some hundred times with the same spacecraft, owing to its capability for repeated operations.

Technically the problem lies in closing the gap between the American test vehicles X-15 and X-20 (Dyna-Soar).

Aerospace transporters of that kind, in principle, promised to attain the required high reliability which should approach that of usual airliners. All the more this becomes true, because the repeated use of the aerospace transporter allows to perform test flights before a final operation. The required high economy is guaranteed not only by the large number of transport missions which probably will be performed with the same standard type, but also by the fact that the costs of an individual aircraft of the production series can be distributed among some hundred of missions practicable with the same aircraft. Finally, the required freedom to profit by usual starting and landing bases in principle seems to be realizable in view of the reduced launching difficulties for piloted winged (i.e. aerodynamic) and – if possible – 1-stage devices which furthermore allow landing like soaring planes.'

In the face of the slowness and myopic nature of national organisations as well as in view of later commercial utilisation of space flight technology, representatives of leading European Aviation industries met in the early 60's with the aim of intensifying their influence in the choice and development of projects, among them Michael Golovine of the Hawker Siddeley Group. Julius Henrici of Junkers, Laurent Janssens and Fernand Vinsonnau of SEREB.

A few days before the constitution of this pooling agreement, the Association Internationale des Constructeurs de

Materiel Aerospactial (AICMA), joined at Konstanz in May 1961 a meeting organised by Sanger with the theme of *Spaceflight and Europe.* Sanger was searching for a suitable European Society as supporter for his Space-Transporter Project; the European spaceflight industrialists on their part were looking for promising projects to orientate their common work and aims. Thus, both partners came together.

On the 21 Sept. 1961 Eurospace – an association of 86 European firms for common industrial development of aerospace techniques was founded in Paris as a sub-organisation of AICMA. On the 4 Oct. 1961 Sanger and his wife were nominated associate members of EUROSPACE by the executive committee of the newly-founded association, and on the 30 Apl. 1963 the management of the project group 'Space transporter' in EUROSPACE was assigned to Sanger.

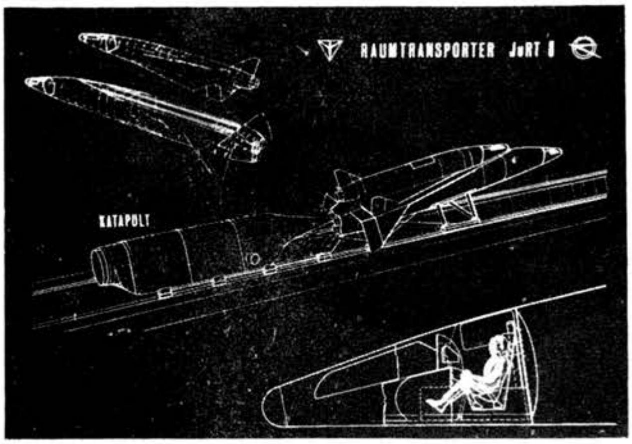
Already on 1 Jul. 1961, he had concluded an agreement with JUNKERS about 'Consultation on the selection of and work on spaceflight developments'. Following his advice, the activities were concentrated on preliminary studies for a smaller, manned space-transporter for antipodal flights or transport missions in a 300 km Earth orbit; the assumptions of these studies were – 180 tons launching weight; 2.5 tons payload in orbit; horizontal catapult launching by means of steam rocket propulsion; also, for the first phase of development, 2 stages with liquid hydrogen – liquid oxygen rocket propulsion of known characteristics (430s).
Following development phase one, a single stage with increased specific impulse (up to 540s) was specified.

Sanger's endeavours met with approval in Germany in that Commission for Spaceflight-Technique responsible for Aero-Space project planning in German industry recommended for the first time in their 1963 research programme, a 'Study Project 623' for the determination of the design parameters for a space-transporter. They allowed a yearly budget of 6.6 Mill. DM and recommended work in collaboration with EUROSPACE.

Sanger summarised his ecperiences and knowledge in the field of recoverable space-transporters, since Aug. 1961, in a comprehensive House Report of JUNKERS, *'Preliminary proposals for the development of a European space-vehicle'*

This report he supplemented and completed to Chapter 32 on the morning of the 10 Feb. 1964, only a few hours. before his sudden death from another coronary thrombosis.

The report, dealt with the scientific, technical, economic and political aspects of the project and, also contained a summary and constructive criticism of the possible variations



Two-stage space transporter studied by Junkers Flugzeug und Motorenwerke (now part of Messerschmitt-Bolkow-Blohm) – in the early 1960's. Dr. Sanger was consultant on this project which incorporated many of his original ideas.

and alternatives of the space-transporter and space-glider projects.

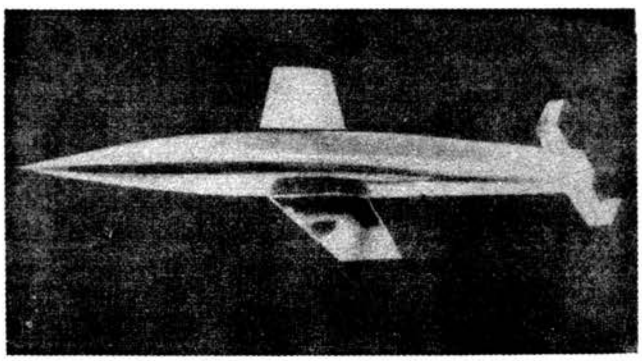
Sanger drew the following conclusion from his investigations:

'It is my firm opinion, for civil use that, the catapult start by means of steam rockets and the main propulsion at first by liquid hydrogen – liquid oxygen high-pressure rocket engines, is the best initial approach. Later on the main stage can be powered by thermal fission rockets. The total launching weight should initially be between 100 and 1000 tons, and the use of one stage vehicles may be justified if catapults are applied.'

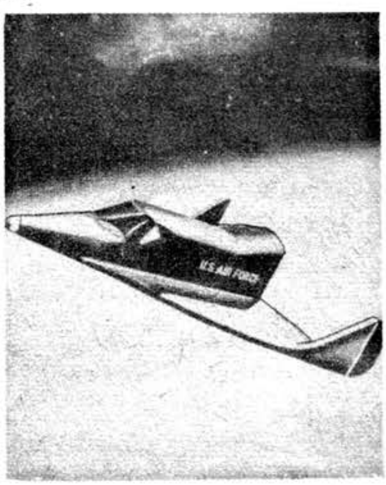
In opposition to the trend towards a vertical takeoff with a lift-to-drag ratio between 2 and 3 in the hypersonic flight range this technique needs less development effort in the beginning. Sanger always insisted upon developing aircraft with high reciprocal gliding ratios and the application of horizontal launching techniques.

A few weeks after Sanger's death an American newspaper article confirmed Sanger's daring expectations, always somewhat doubted in Europe. It said:

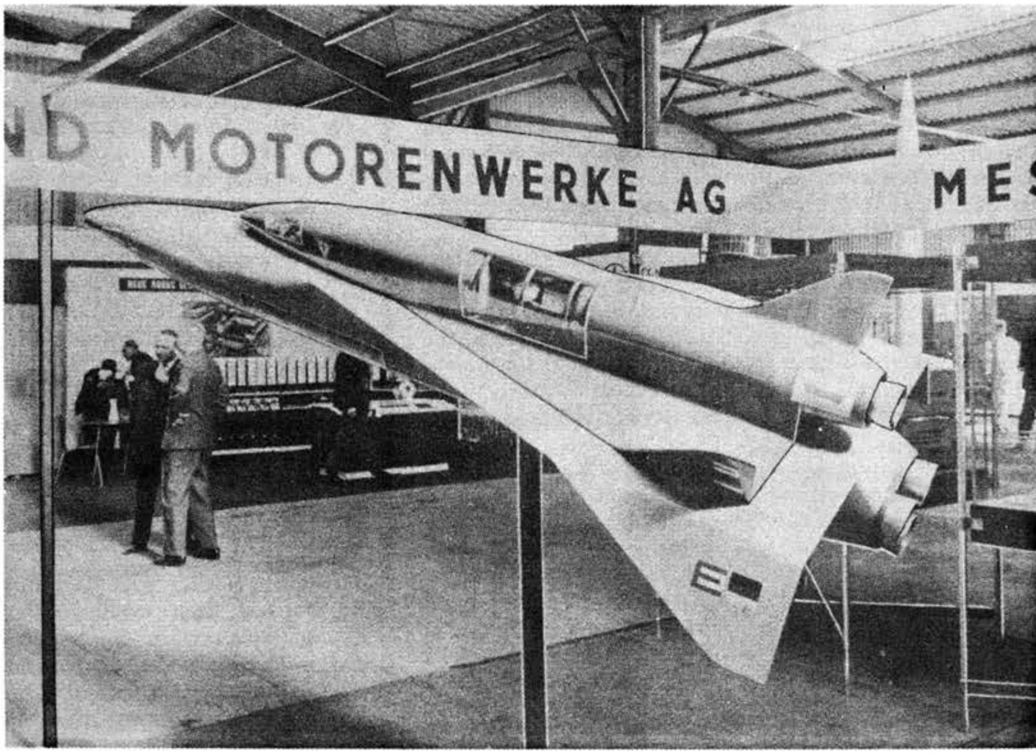
'According to studies of the United Aircraft Corporation which were carried out by commission of NASA, outward



Wind tunnel model of the antipodal rocket bomber (1938-1942).



Boeing X-20 Dyna-Soar abandoned by the U.S. Air Force in 1963. Although intended to be launched by Titan 3C, the one-man space-plane followed principles established by Sanger a quarter of a century earlier. The project was one stage removed from the much larger NASA space shuttle orbiter of today. Length 10.7 m; wing span 6.09 m, height (with wire-brush landing skis retracted) 2.4 m.



Scale model of the Junkers space transporter project at the Hanover Air Show in 1966.

'Flight International'

and return flights to the Moon with a one stage space-transporter-system lie in the region of possibility. According to the firm, they are now working on studies for a one stage space-transporter which will be equipped with a gaseous core nuclear rocket. Such nuclear propulsion engines would make feasable loading capacities up to 30% of the launching weight and would also offer the economical advantages of a recoverable space-transporter system.

The operation of such a highly developed propulsion system demands a controlled reaction of the gaseous nuclear fuel under extremely high temperatures. In this case the walls of the engine are to be shielded by a layer of cold gas. According to the firm, the results gained and still expected in the ROVER-programme can provide a great deal of the technology required for the development of a recoverable gaseous core nuclear rocket'.

Eugen Sanger did not live to see the realisation of his creative dream of the 'Silver Bird'. However, 3 years before his death on 12 Apl. 1961, he learned that the Russian, Yuri Alekseyevich Gagarin, had succeeded in a manned orbital flight around the Earth. More than 5 years after his death, on 21 Jul. 1969, the American Neil Armstrong was the first man to set foot on the surface of the Moon.

With the event began the 'interplanetary phase of manned spaceflight' with the realisation of the space-transporter, predicted by Sanger for some time in the 1970's.

May the defiant motto of Eugen Sanger's youth become true:

'Nevertheless, my Silver Birds will fly!'

(Grateful acknowledgement is made to Mrs. I. Berrer, who undertook the initial translation from the German text and to Mr. V. Johnson and Mr. W. Withey for editorial help).

SLINGSHOT TO SATURN

Ninety scientists from the Unites States and 4 foreign countries have been selected to participate in the Mariner Jupiter/Saturn 1977 mission. This group was chosen by NASA from more than 200 scientists who submitted proposals in response to NASA's invitation in April 1972. The scientists represent 32 institutions in the United States and 5 abroad. Foreign Countries represented are France, Sweden, West Germany, and the United Kingdon.

The scientists are grouped into 11 investigation areas. Each investigation area will be represented on the MJS77 Science Steering Group which will be responsible for the overall science programme and will work with the engineers and mission planners to design the spacecraft and the details of the mission. Except for Imaging and Radio Science, for which instrumentation will be furnished by the MJS77 Project, the individual science groups will be responsible for design and construction of the instruments associated with their investigation areas.

The MJS77 mission was developed in an earlier phase which was initiated in 1971 as part of an approved programme of Outer Planets Missions. The mission will involve launching 2 Mariner-type spacecraft in 1977 to fly by Jupiter and, being

accelerated by Jupiter's gravity and orbital velocity, to subsequently fly by Saturn. In addition to flybys of the planets, close flybys of various moons of both planets should be possible.

The spacecraft will encounter Jupiter in a little over 1.5 years and Saturn 3.5 to 4 years after launch. The two spacecraft will have identical instrumentation; however, they may have differing trajectories, allowing each to pursue a different set of specific scientific objectives.

The mission offers a particular challenge to scientists and engineers. Not only is it to explore a region unexplored by man, but the four-year flight programme also offers a challenge in the amount of data to be obtained and in lifetime of the instruments. NASA has adopted a conservative approach to this mission by using, where possible, proven spacecraft hardware to increase the chance of success and to hold costs to a minimum.

The MJS mission will take advantage of data from the Pioneer 10 space probe which is now more than half way to Jupiter. The results of the Pioneer mission are expected before the final design of MJS mission and spacecraft are complete. While the Pioneer spacecraft is especially suited to studying environment from Earth out to Jupiter, the Mariner spacecraft is equipped to concentrate on remote sensing required to explore Jupiter and Saturn, their satellites, and the rings of Saturn. The Mariner will be designed for a four-year lifetime to be able to reach Saturn and possibly beyond.

The overall objectives of the MJS77 mission are to conduct exploratory investigations of the Jupiter and Saturn planetary systems and the interplanetary mediums out to Saturn. The science groups and their investigations are:

(a) *Imaging:* Visually characterise Jupiter, Saturn, their satellites, and the rings of Saturn.
(b) *Radio Science:* Study the atmosphere of Jupiter and Saturn and their moons, the size of the particles in the rings of Saturn, and interplanetary physics, using the telecommunications systems of the spacecraft.
(c) *Infrared Spectroscopy and Radiometry:* Study both the global and local energy balance in conjunction with measurements of reflected solar energy; determine the atmospheric composition, including the ratio of hydrogen to helium and the abundance of methane and ammonia; and investigate the composition, thermal properties, and size of particles in Saturn's rings.
(d) *Ultraviolet Spectroscopy:* Analyse the atmosphere of Jupiter, Saturn, and encountered satellites for their major constituents, including the mixing ratio of hydrogen and helium and the thermal structure of the atmosphere, using an ultraviolet spectrometer.
(e) *Magnetometry:* Study the magnetic fields of Jupiter and Saturn, and the interplanetary magnetic field out to its boundary with the interstellar magnetic field, if possible.
(f) *Plasma:* Determine the properties of the ions in the solar wind, obtaining accurate values of their velocity, density, and pressure and determine their interactions with the planets Jupiter and Saturn.
(g) *Low Energy Charged Particles:* Study the magnetosphere and trapped radiation belts of Jupiter and the possible magnetosphere trapped radiation belts in the vicinity of Saturn; and separate and analyse the low energy galactic cosmic ray particles.
(h) *Interstellar Cosmic Rays and Planetary Magnetospheres:* Determine the energy and identity of medium to high energy galactic cosmic ray charged particles and of the higher energy trapped planetary energetic particles.
(i) *Interplanetary/Interstellar Particulate Matter:* Detect and determine range and velocity of particulate matter through detection of reflected solar radiation and counting particle impacts by light flash and acoustical means.
(j) *Photopolarimetry:* Measurements of refelection and scattering properties of particles in the atmospheres of Jupiter and Saturn, their moons, and the rings of Saturn, using photometric and polarimetric techniques.
(k) *Planetary Radio Astronomy:* Record and study planetary non-thermal emissions of Jupiter and Saturn and the plasma resonances in the magnetosphere of these planets.

Members of the NASA-formed teams, Principal Investigators and Programme and Project Scientists are:

Imaging Team:
B. Smith, New Mexico State University (Team Leader).
A. F. Cook, Smithsonian Astrophysical Observatory.
G. E. Danielson, Jr., Jet Propulsion Laboratory.
M. E. Davies, Rand Corporation.
G. E. Hunt, Meteorological Office, England.
T. Owen, State University of New York.
C. Sagan, Cornell University.
L. Soderblom, United States Geological Survey.
V. Suomi, University of Wisconsin.

Radio Science Team:
V. R. Eshleman, Stanford University (Team Leader).
J. D. Anderson, Jet Propulsion Laboratory.
T. Croft, Stanford University.
G. Fjeldbo, Jet Propulsion Laboratory.
G. S. Levy, Jet Propulsion Laboratory.
G. L. Tyler, Stanford University.

Principal Investigators:
Infrared Spectroscopy and Radiometry R. A. Hanel, Goddard Space Flight Center.
Ultraviolet Spectroscopy A. L. Broadfoot, Kitt Peak National Observatory.
Magnetometry N. F. Ness, Goddard Space Flight Center.
Plasma H. S. Bridge, Massachusetts Institute of Technology.
Low Energy Charged Particles S, M. Krimigis, Johns Hopkins University.
Interstellar Cosmic Rays and Planetary Magnetospheres R. E. Vogt, California Institute of Technology.
Interplanetary/Interstellar Particulate Matter R. K. Soberman, Drexel University/General Electric.
Photopolarimetry C. F. Lillie, University of Colorado.
Planetary Radio Astronomy J. W. Warwick, University of Colorado.

Programme Scientist
M. A. Mitz, NASA Headquarters.

Project Scientist
E. C. Stone, Jet Propulsion Laboratory and California Institute of Technology.

THE LAST APOLLO — 4

EXCURSION TO MARSHALL SPACE FLIGHT CENTER HUNTSVILLE

By Dr. W. R. Maxwell.

The visit to Cape Kennedy, organised by Transolar Travel, to witness the lift-off of Apollo 17 included for the first time an optional excursion to the Marshall Space Flight Center at Huntsville, organised in conjunction with the BIS. It lasted for approximately a day and a half and involved flying from Orlando Airport to Huntsville on the afternoon of 7 Dec. and returning in the late afternoon of 8 Dec. the night being spent in the very comfortable Sheraton 'Wooden Nickel' Motel. The excursion had a particular relevance on this occasion because those taking part were able to see the so-called 'breadboard' model of the Apollo 17 launch vehicle which had been used to verify the proposed solution to the problem in the pressurisation of the second stage which led to the 'hold'.

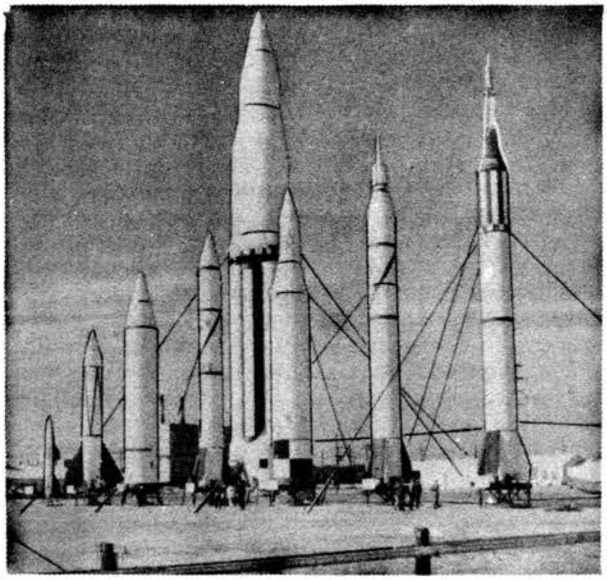
On the morning of 8 Dec. the party were first transported to the Alabama Space and Rocket Center where NASA's Marshall Space Flight Center and the US Army Missile Command are represented jointly with the aerospace and missile industry in an impressive collection of indoor and outdoor exhibits. The party first entered the lecture theatre where a short address of welcome was delivered by the Center's Director, Edward, O. Buckbee. Georg von Tiesenhauser then delivered a very interesting lecture accompanied by slides which covered many aspects of NASA's activities including the purpose of the Apollo 17 mission, Skylab, the Space Shuttle, the Space Tug, Sortie Modules, planetary missions and Earth resource satellites. On the latter he said that as a result of information obtained from Earth resource satellites many new geological features had been discovered in California and geologists were now swarming all over the area.

NASA was clearly encouraging the young to take an interest in space activities and had invited boys and girls to submit proposals for experiments to be carried out in Skylab. Several interesting proposals had been obtained including confronting a spider with the problem of how to build a web under zero gravity conditions. As a contribution to the anti-pollution drive the lecturer gave an interesting account of NASA's studies on solar electric power. They are currently studying a power plant of 100 kw capacity and in a year's time will follow on with a similar study of a plant of 100 MW capacity. The generation of electricity depends on thermo-electric conversion.

After the lecture, which was clearly and expertly delivered, there was a period for questions and it was apparent from the number of questions asked that the lecture had aroused much interest. At the conclusion of the questioning period the party was released into the exhibition building from which they then had easy access to the outside exhibits.

The exhibition building contained a wide variety of exhibits relating to all aspects of the exploration of space and a number of these permitted audience participation. The most popular of the latter was a small rocket engine which could be fired and the thrust measured. Another attraction was the 'monkeynauts', Miss Able and Baker, who were launched into space on 28 May 1959 and were the first animals to be recovered alive; they appeared to be in very good condition. A major exhibit of great interest was entitled 'The Dimensions of Space' and consisted of a darkened labyrinth containing illuminated photographs relating to the heavenly bodies with a large central hall filled with a model of the solar system.

Outside the exhibition hall were many of the vehicles used by NASA at various stages of the space programme and also a number of army missiles. There was also a lunar module with astronauts in a lunar setting. By far the greatest attraction was a Saturn V launch vehicle lying horizontally with the inter-stage fairings removed. The Alabama Space and Rocket Center is the only place where a Saturn V vehicle can be examined at close quarters and a true impression obtained of its size. Viewing of the vehicle in the Vehicle Assembly Building at Cape Kennedy is not permitted and when it is on the launch pad visitors are only able to view it from a very considerable distance so that no true impression of size can be obtained. It is a memorable experience to be able to stand right alongside the cluster of giant F1 nozzles at the rear end of a Saturn V.



A magnificent display of vintage rocketry dominates the landscape at the Marshall Space Flight Center's Space Orientation Center. Left to right are: Hermes, modified V-2, Jupiter, Redstone, Saturn I, Juno II, Jupiter C, and Mercury Redstone.

National Aeronautics and Space Administration

The visit to the Alabama Space and Rocket Center ended at about mid-day and a bus with a technical courier was then boarded to commence a tour of the Marshall Space Flight Center. The centre occupies 1800 acres inside Redstone Arsenal which itself occupies 25,000 acres. Redstone Arsenal played an important part in the early American space programme and the Redstone missile, Jupiter C and Saturn I, were developed here.

The Marshall Space Flight Center (named after General George C. Marshall of Marshall Aid fame) was formed on 1 July 1960 by the transfer of buildings and personnel comprising part of the Army Ballistic Missile Agency from the US Army to NASA. The bus tour which was interrupted for lunch at the Centre's canteen, took the party past a wide variety of buildings, test stands and storage areas whose purpose was described *en route*, but stops were made at only two points. The first of these was in the vicinity of the two test stands used in the development of Saturn V. One of these stands is used for the routine testing of F1 engines before assembly into the Saturn V first stage and the other and larger test stand is used for the testing of the complete first stage. As might be imagined this test stand is a very massive

structure. An interesting feature is that the water-cooled baffle at the base of the stand is designed to deflect the exhaust upwards through perhaps an angle of about 15° so that it clears the ground and the trees in the vicinity. The Saturn V 1st stage generates a noise of 178db at 200 ft. and in order to prepare those in the surrounding areas a large horn is operated before the stage is tested. The Saturn V stages are assembled at the Marshall SFC but the 1st and 2nd stages on their vehicles are too high to go under bridges and they are therefore placed on barges in the River Tennessee whence they proceed via the Ohio and Mississippi into the Gulf of Mexico whence they follow the coast round Florida until they can enter the waterways at Cape Kennedy.

The party was next transported to the Systems Development Complex which was in a large building labelled 'Quality and Reliability Assurance'. Here was the so-called 'breadboard' model that had helped solve the problem involved in the 'hold' on Apollo 17 two days before. It was in fact very different from the normal conception of a 'breadboard' and could best be described as an electro-mechanical simulator built up from tanks, pipes, valves and the like. In the same complex was a complete Saturn V instrument unit which is in the form of a ring on the top of the third stage. A large number of computers and associated equipment could also be brought into play for the purpose of launch vehicle sequence testing. The whole set up gave a good impression of the kind of back-up that is behind every Apollo launch. Before leaving the Marshall SFC a short visit was made to another building where there was a small model of the space shuttle in its most recent form and larger mock-ups of space shuttle hardware including a General Purpose Laboratory for various orbital application experiments involving the shuttle.

To sum up, an excursion to Huntsville is very worthwhile for those who have a strong interest in rocket propulsion and launch vehicles. It is the only place where a Saturn V vehicle can be examined at close quarters and for many this alone would justify the journey from Florida. Huntsville is known as the 'Rocket City'. It is an excellent place to see rockets, but nothing else!

VISIT TO HOUSTON

Some 70 participants left the delights of Florida on the two day excursion to the Manned Spacecraft Center at Houston. The solid strength of their enthusiasm was shown by their monlithic response to the 5.15 am. call for the only flight of the day from NASA's launching facility to the control centre for astronautics.

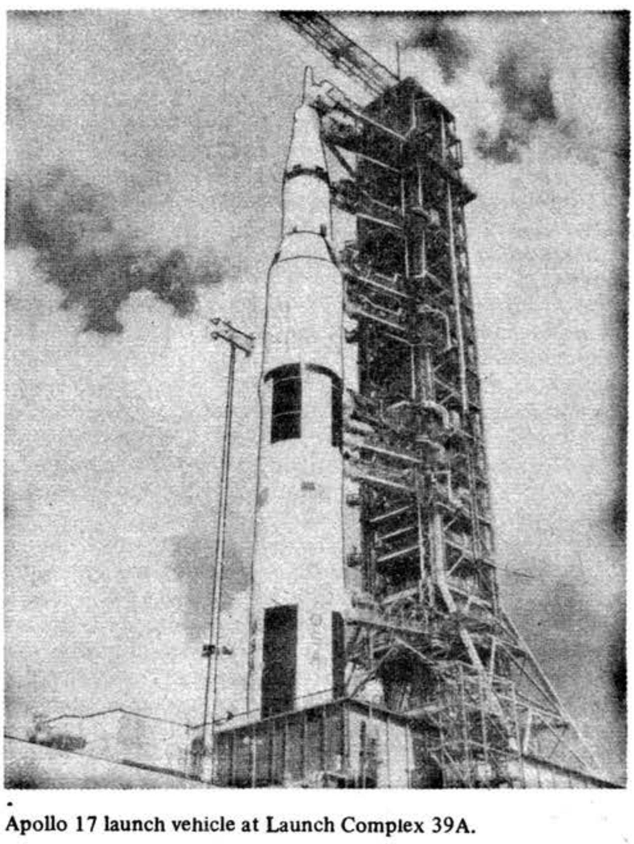
Here at Houston is to be found a facility on a truly Texan scale – some 35 major buildings in a complex occupying 16000 acres. Its functions cover;

1. Development of the technology required for operation of manned spacecraft.
2. Management of industrial procurement of spacecraft.
3. Selection and training of NASA astronauts.
4. Control of manned space flights (from about 10 sec. after launch through to landing on Earth).
5. Medical, scientific and engineering experiments during manned space flights.

Some 10,000 workers are engaged on these activities, about two-thirds from Industry and one third in the Government service.

Only a quite limited part of this large undertaking is normally open to the public. This includes the Mission Simulator and Training Facility, the Flight Acceleration Facility and a very well furnished museum known as the Visitor Orientation Center. Our party was however especially privileged to see also some of the normally restricted parts, in particular, the Missions Operations Control Room (MOCR), the Lunar Receiving Laboratory (LRL) and the environmental facility. On this tour, the party was conducted by two very articulate and knowledgeable guides, who seemed particularly pleased to be conducting a group that included no US taxpayers! It was noticeable that, even so, they had no information on costs, though they responded very readily on all technical and organisational questions. The one financial exception was the tit-bit that the whole site had been leased at a rental of $1 per year from the University, to which it would revert when NASA had no further use for it.

The MOCR is the facility so well known from TV coverage of Apollo. The party was shown the upper room, being readied for Apollo 17. Below, a duplicate room was being set up for the Skylab launch due in May. It was explained that each of the consoles in this nerve-centre is supported by about 100 other 'component' rooms with consoles elsewhere and by a large computer facility in the basement. A graphic picture was drawn by the guide of how this complex operates and how emergencies are dealt with. When necessary, the results of any proposed course of action can be computed 40 hr.



Apollo 17 launch vehicle at Launch Complex 39A.

National Aeronautics and Space Administration

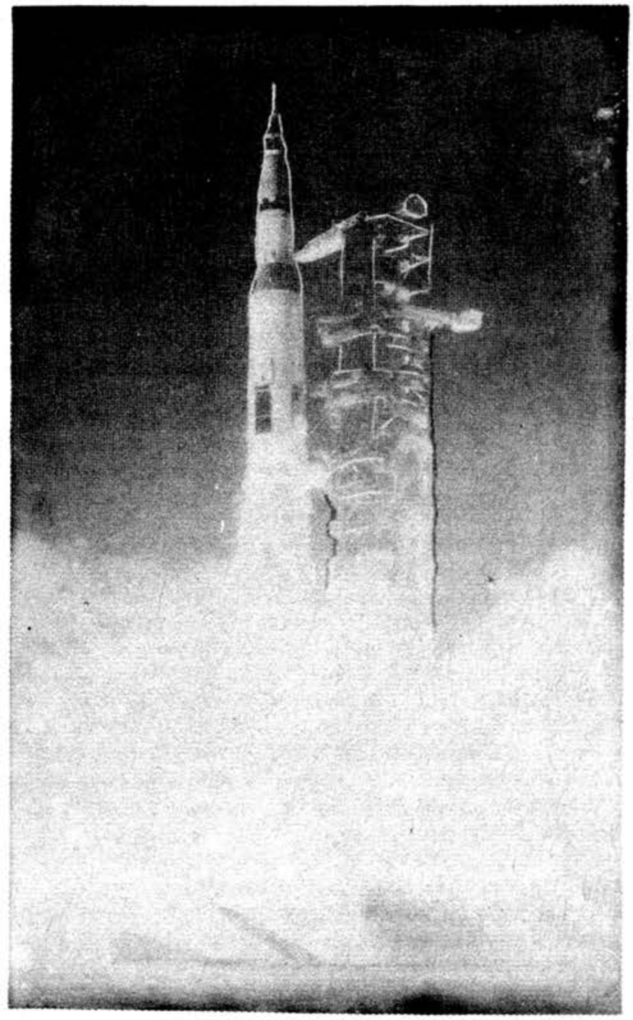
ahead. One feature specially stressed was the small 'media' cabin with desks for two elected representatives, one from the press and one from TV, who can observe all that takes place and receive all discussion in the control room, though it is not available for transmission. At all points, the most careful attention is paid to public relations and it is sad to think that this is not self-advertisement but an attempt to meet the continual attacks of the anti-space lobby.

In the LRL examples of lunar material were on display, not the original rocks but copies or 'phantoms' made for each before it is broken down or otherwise treated for scientific analysis. The party was also shown the 'glove box' line in which the original sorting and preparation work is done.

At the environmental facility, one was overwhelmed by the simulation chamber – especially impressive to those familiar with the thermal vacuum chambers installed in Europe for unmanned satellites. This chamber is of 65 ft. diameter and stands 120 ft. high. It can accommodate a vehicle up to 25 ft. diameter and 65 ft. high, sufficient for any spacecraft. The internal conditions can be reduced to 1×10^{-6} torr pressure and -280° F. A large carbon arc equipment simulates the solar heating and it is interesting that, in this case, no change to xenon lamps is proposed.

The centrifuge at the Flight Acceleration Facility is also very impressive. This is the largest man-rated centrifuge in the free world. The 10600 hp motor can get the 50 ft. arm up to 42 rpm, corresponding to 168 mph or 30 G. Human subjects have been taken up to 15 G for a few seconds. There is auxiliary usage as a Lunar Gravity Simulator, in which the rotor becomes simply a supporting arm reducing gravity, in effect, to 1/6 G.

The mission simulator building was closed at the time of the visit, for reasons connected with the current mission. Nevertheless, what had been seen constituted a field day for the enthusiasts who made the trip.



We have lift-off! Apollo 17 starts astronauts Eugene Cernan, Ronald Evans and Harrison Schmitt on America's last scheduled journey to the Moon.

National Aeronautics and Space Administration

AN ACCOUNT OF THE LIFT-OFF

By E. Jonothan Shamah

We asked one of our London members to give his personal impressions of launch day. This is his account.

At 6-30 p.m. on that hot December day my coach, one of five from Daytona Beach, drew out of the motel and headed towards Kennedy Space Center – launch site of the last manned lunar flight of this decade. The whole coach pulsated with an air of excitement; at last we would see the launch.

We were all worried beforehand that the strike by Boeing personnel would cause a delay which would not enable us to observe the launch. These fears were now dismissed and the launch was continuing as scheduled. Those of us accomodated in Daytona Beach were now used to the 1½ hr. journey to the Cape area. There was much to keep us occupied on the way. Through the window one could see on the horizon the glow of many searchlights. We could also see in the sky, many clouds accompanied by a strange form of lightning which lit up the entire panorama, like a flare. I recognised this phenomenon – we were plagued with this at the time of the Apollo 15 launch also.

As we left the highway, which appeared to be a toll road, we saw our first real glimpse of the last Apollo-Saturn 5 to go to the Moon, shining a pillar of light across the waters of Indian River. It was arranged that we would view the lift-off from inside Kennedy Air Force Station, so our hopes were high for a fantastic position to view the lift-off. When we finally reached the gates the coaches came to rest by the side of the road – and waited. After many anxious minutes the rest of our group, who came from Cocoa Beach, arrived with the security passes and we were let through the gates.

The road curved towards Launch Complex 39. The rocket loomed larger and larger illuminated by a multitude of searchlights. Our convoy, now consisting of nine coaches, pulled up by the verge. Through the tinted windows one could observe viewing stands; we all thought this spot was indeed excellent. We were no more than four miles from the 'pad'.

'Don't let them out of the coaches', we heard – we were

not fated to be occupants of a VIP viewing area! We headed back towards the entrance gates. Just outside the coaches turned off the main road. Our final resting place was reached.*

My coach was second in the line resulting in a very long hike for me to where we would see the launch – the Banks of Banana River. The sky was clear; the stars shone brilliantly – perfect conditions for a launch. Around me were many different people, not only from our groups. Several people were dancing to rock music, the radio blaring; after all this was an attraction not be missed – a 'family outing'.

Countdown continued as scheduled. The time slipped quickly by – 'T-minus 10 min. and counting – all systems look good'. The time was approaching – the sky remained clear. The final 1 minute of countdown had started.

The totally unexpected hold caught everybody by surprise. I don't think it struck people that the lift-off was delayed until after several seconds. Over the radio we were told that after a long delay the countdown would resume at T-minus 22 min. The rock music started again. At least it gave the press something to write about. On the radio, commentators, ad-libing as best they could, were recounting past happenings at the Cape, humorous stories and such like, interspersed with commercials. After one hour the sky clouded over, cleared and then clouded up again. The mist on Banana River was quite worrying; nevertheless, at the second T-minus 30 sec. their was no hold, and the countdown continued.

The sky lit up from the fury of the five F-1 engines of the first stage rising from the smoke; the vehicle, belching flame, rose higher through a layer of cloud and upwards, illuminating the sky like a miniature sun. The roar of the engines was not as loud as expected due to our distance, but nevertheless it was the unmistakable sound of a Saturn 5 lift-off. The rocket, burning seven tons of fuel every second and with 7.7. million pounds of thrust directed behind it, curved down the test range over the Atlantic – visible within a 500 mile radius, on its long trip to the Moon. The engines of the S-1C shut down, the sky dimmed. A burst of light indicated that the retro rockets separating the first stage from the rest of the vehicle had fired. The second stage ignited. The rocket moved away, a star in the sky diminishing every second. From the beginning of the launch, one could not actually see the rocket itself; the flames were too bright, but now even they had dimmed as the craft was building up speed to orbital velocity. It was impossible to wait for EOI confirmation as the traffic would have been too dense to go back to the motel. We made our way back to the coaches, avoiding the endless stream of cars leaving the Cape.

The return journey to Daytona Beach was not uneventful. Two coaches were stopped by the Highway Patrol for driving abreast of one another, and another stopped when its lighting system failed. By the time a replacement bus came and they finally got back to the motel, it was 6-30 a.m., three hours after the rest of us.

Thus Apollo 17 was on its way to a rendezvous with Taurus-Littrow. It was already on the trans-lunar coast before we were even back at the motel – ahead of it lay man's most historic flight.

* *On this historic launch, the demand for accomodation greatly exceeded that available. Over 2 million Americans jammed the roads for miles around, seeking the best vantage points. The Transolar party was fortunate in being given special permission to view the launch from a USAF site, even though it was some way off.*

VOYAGE BEYOND APOLLO

By Eric Burgess, FBIS

While Apollo 17 completed its final mission to the Moon thus virtually ending the US manned space flight programme interplanetary phase of exploration, scientists, engineers, science fiction writers and novelists, artists and philiosophers, explored with a group of holidaymakers the role of space flight in the voyage of mankind. Many old-time participants likened the experience to the old days of the interplanetary societies since very few limits, if any, were placed on the thoughts and the discussions.

The occasion was a Carribean cruise aboard the *SS Statendam* on which about 1 of every 6 passengers had paid extra to participate in 10 days of space oriented seminars. Dr. Isaac Asimov, one of the speakers, summarised the theme of the seminars when he said: 'We represent the Universe becoming aware of itself, and we may meet another piece of the Universe also becoming aware of itself. We have then to recognise that we are all different aspects of the highest development of the Universe'. He added that mankind has suddenly realised that the world is finite and that there is no longer opportunity for the historical bungling approach to managing its resources. But a human colony on the Moon may teach men on Earth how not to muddle along because there is 'no room for error on the Moon'.

Richard Hoagland, one of the organisers of the seminars, explained that the space Shuttle was essential to continued exploration of space by men. It was pointed out, however, that today's 'poor man's' space Shuttle with continued NASA cutbacks, will not take men back to the Moon. A new generation of spacecraft beyond the Shuttle will be needed before an American can again set foot on another world.

Highlight in the voyage was the grandstand view from 8 miles offshore of the night launching of Apollo 17. Deep emotions coloured the comments afterwards, even from those who had witnessed earlier launches.

A question asked many times by participants was what does the space programme mean in the context of the broad story of mankind. Dr. Krafft Ehricke, one of the engineers associated with the German V-2 project at Peenemünde during World War II and now a senior scientist at North American Rockwell, explained that man's expansion into space is a natural process essential for continued development from the biosphere – the living sphere – here on Earth. 'It is now time for the industrial machines to emigrate', he said. With several other speakers he described the advantages of manufacturing operations on the Moon instead of Earth to make this planet virtually pollution-free. Speakers showed how finished products could be transported relatively inexpensively to Earth by advanced propulsion systems. The Moon contains much oxygen explained Dr. Ehricke and showed how nuclear explosions could release this oxygen and make water plentiful on the Moon.

That the limit to what man can do in the material world lies solely in man's thinking was stressed by several speakers. And, it was claimed, unexpected breakthroughs have invariably made all the prophets of doom wrong in the past. Commenting on the Club of Rome's limited attitude to continued growth, Dr. Ehricke said; 'We are like a baby in the womb basing its future on staying in the womb if we do not look at expansion into space as part of the future'.

Another big question raised by seminar participants – which included lawyers, housewives, teachers, students, accountants, to name a few – was why the American public had turned its back on the space programme in particular and science in general. Robert Heinlein, dean of science fiction writers, likened the current turning away from science as a pause rather than an end. And Dr. Marvin Minsky, MIT's expert on artificial intelligence, likened the present wilderness of human thought to an 'exploropause'. He asked; 'Can scientists keep their enthusiasm while crossing the waterless desert of today?' He pointed out that 'teleoperators' being researched for space flight could relieve men from working in mines but that no money is being spent for the development of such machines.

Norman Mailer lamented that; 'This (Apollo) programme was the most heroic endeavour of the US since the settlement of the West'. The proportion of the GNP spent on the transcontinental railroad was incidentally about the same as the proportion of today's GNP spent on the Apollo programme. Continued Mailer; 'NASA took one of the most profound events of the 20th Century and achieved the miracle of making it monumentally boring and totally depressing'.

Other speakers said that the blame was not entirely NASA's but that the mass media failed to explain the programme properly, giving more attention to unimportant factors, like talking about plumbing without explaining what the pipes were carrying and why.

Commented one lady participant after a lecture detailing the results of the Mariner 9 mission to Mars: 'Why hasn't anyone told us of these exciting things?' A writer at the seminar explained that Soviet coverage in major newspapers of their probes Mars 2 and 3 was much better than American coverage of Mariner 9 in equivalent US newspapers. Soviet coverage was technically detailed and talked up to the reader. US coverage was meager and generally talked down. He stressed that a major crisis faced the nation in a disenfranchisement through ignorance. A communication crisis deluges the people with colourful trivia.

Roger Caras, vice president of the company which produced the motion picture '2001 – A Space Odyssey', said the American public has turned away from many other important things as well as the space programme. He suggested that mankind may be entering into a very critical stage of human experience. 'We are so overcommunicated that we cannot maintain interest in anything beyond the novelty stage'. By contrast the Indonesian crew of the *SS Statendam* showed unusual interest in Apollo and what it meant. They asked many questions of the speakers and expressed disappointment that they could not attend the lectures. Several asked for copies of the papers to be mailed to them later.

Dr. Carl Sagan, Cornell University, explained why a manned mission to Mars should not be attempted yet. Mars and Earth could contaminate each other. The Apollo quarantine just did not work, he said. It is not feasible to isolate Earth from the life forms of other planets if men visit them. Calling for exploration of the outer planets, he deprecated the cancellation of the unique Grand Tour mission to all of them. He claimed that the cost of a single day of the Vietnam war would have payed for 10 years of planetary exploration. Only by studying the planets can men really come to understand the Earth itself.

Dr. Sagan also suggested that a major task of mankind should be to seek signals from extraterrestrial intelligences. But nothing is being done or planned to this end in the US today. He pointed out that the major impact of the plaque carried by Pioneer 10 towards the stars is a message to all earthmen. They should become increasingly aware of the role that they may be destined to play against the cosmic background.

SPACE REPORT

A regular monthly review of Space Events and Technical Trends

SPACE TUG STUDIES

The Marshall Space Flight Center has invited the aerospace industry to submit proposals on the study of Space Tug Systems. The Space Tug, to operate in conjunction with the Space Shuttle, in effect would become the vehicle's third stage extending its capability. Some anticipated shuttle payloads will need additional propulsion for achieving higher orbit, for example, geostationary orbit. That propulsion would be provided by: (a) the use on a temporary basis of an existing rocket stage such as the Centaur or Agena which would be adapted for launch from the shuttle cargo bay, or (b), the use of an interim tug the possible development of which is to be studied under this new effort.

The interim tug would offer far more capability than the temporary use of an existing rocket, and would provide the foundation for the development of the full capability tug which is one of the main components of the Space Transportation System in long-range US space planning.

Four companies have been selected by NASA's Marshall Space Flight Center, Huntsville, Alabama, to study space tug systems. General Dynamics, Convair Aerospace Division, San Diego and McDonnell-Douglas Astronautics Company, Huntington Beach, California, will be working under identical specifications for a 'cryogenic' tug, using liquid hydrogen and liquid oxygen propellents. Grumman Aerospace Corporation, Bethpage, N.Y., and Martin-Marietta, Denver, will perform similar parallel studies of a tug which would use storable type propellents.

These four studies, jointly funded by NASA and the Department of Defense and costing about $750,000 each, will require 10 months to complete. DoD will assist in the technical management of the studies.

The interim tug would be developed in time for use in the first flights of the Space Shuttle, which is to be operational in the late 1970's. Uses planned for the tug include the transfer of cargo from orbit or in near-Earth space and launch of payloads from low Earth orbit to intermediate and geostationary Earth orbits. It would also be used for launching unmanned planetary missions from the Shuttle.

In each mission the tug would be ground-based; that is, it would be fuelled on the ground, launched from the Shuttle

in low Earth orbit, recaptured by the Shuttle and returned to Earth for repeated use.

NEW FRENCH LAUNCHER

The L.3S launcher that France has offered as a substitute for the abandoned ELDO Europa III has been put forward as a possible European project within the context of the proposed European Space Agency. Britain has already made it plain that it will take no part in the project but West Germany may well participate, especially if France contributes to the Spacelab sortie-module for the Space Shuttle.

The Viking II engines for the L.3S are already under joint development by SEP of France and MBB of West Germany. The first stage of the new rocket is, in fact, virtually the same as the stage which was being developed for Europa III.

First drawing of the L.3S released by the Centre National d'Etudes Spatiales shows a 45 metres (147.6 ft.) tall vehicle with a diameter of 3.8 metres (12.4 ft.) across the first stage tanks. With a total launch weight of 200 tonnes, the vehicle is designed to place a 750 kg (1,653 lb.) payload into a geostationary orbit.

First stage: L.150 is powered by four pump-fed Viking II engines, with a total thrust of 241 tonnes, s.l., 279 t. vac. Total propellent load is 140 tonnes (50 tonnes UDMH and 90 tonnes N_2O_4. Specific impulse (vac.) 279 sec. Thrust duration 140 sec. Total mass structure 13.5 tonnes.

Second stage: L.35 is powered by a single pump-fed Viking II engine, with a thrust of 69 tonnes (vac.) Propellents: 12 tonnes UDMH, 23 tonnes N_2O_4. Thrust duration 140 sec., specific impulse 285 sec, structural mass 4 tonnes.

Third stage: H.6 is powered by gas pressure-fed four-chamber HM-4 engine of 6 tonnes thrust. Propellents: 1 tonne liquid hydrogen, 5 tonnes liquid oxygen. Specific impulse 420 sec., thrust duration 412 sec. structural mass about 1 tonne.

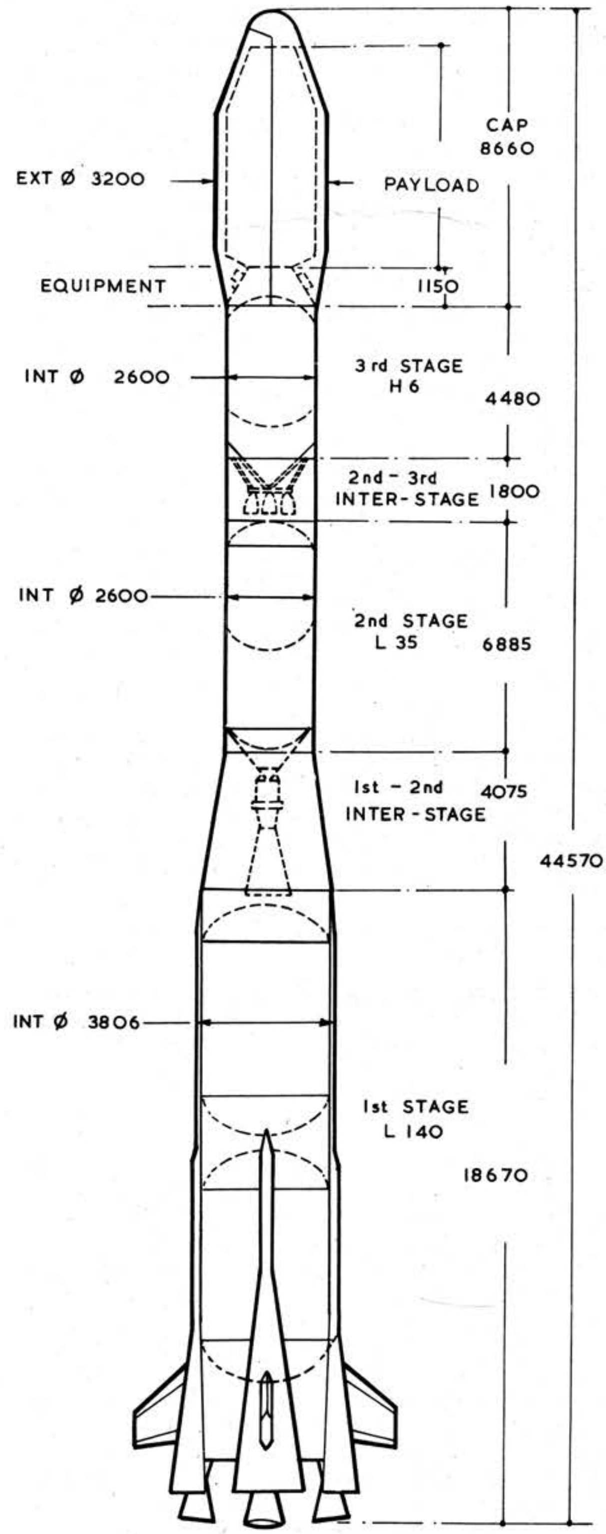
Instrument unit above third stage includes guidance package, sequencer, telemetry, telecommand, and radar transponder.

Estimated development cost: 2210 million francs (£175m); launch cost about 61 million francs (£5m) each.

It is planned to have the first qualification test of the cryogenic stage in 1977. Two qualification launchings of the complete three-stage vehicle are expected in 1979. If this schedule is met, the L.3S should be operational in 1980.

MASCON AWARD

Scientists Paul. M. Muller and William L. Sjogren of the Jet Propulsion Laboratory, Pasadena, have received a major monetary award from NASA in recognition of their discovery of mascons or mass concentrations of dense material beneath the Moon's surface. The 1968 mascon discovery and the imaginative interpretation of its results and implications, made by the two JPL scientists, proved of significant value to the success of the Apollo programme. Their work is expected to be equally important in future studies of the Earth



First drawing to show the configuration of the proposed new French launch vehicle L-3S which may be developed in conjunction with West Germany and other European partners. The British Government has no interest in this project.

Centre National d'Etudes Spatiales

and other planets.

The $10,000 award was recommended by NASA's Inventions and Contributions Board following a detailed evaluation of the merits of the scientific contribution. Muller and Sjogren's contribution involved three note-worthy developments:

(1) Their method provided precision gravimetric data for the first time, using only the facilities of Earth tracking stations to receive signals from orbiting spacecraft, indicating velocity variations. Such speed changes were recorded in the Doppler cycle count – in the frequency difference or 'Doppler shift' between the transmitted and received signals. Analysis of the Doppler phenomena by relatively modest computer calculations provides prompt, precise data on lunar gravity fields.

(2) The two-man team used their data to plot the first gravimetric map of another planetary body. The map proved of major scientific importance and led to the solution of puzzling gravity anomaly problems posed by Lunar Orbiter 5 tracking data.

(3) In plotting spacecraft velocity changes, Muller and Sjogren found that the speed increased and then returned to normal each time the vehicle overflew any one of five circular or ringed maria – *Imbrium, Serenitatis, Crisium, Nectaris* and *Homorium.* A sixth mascon was located between *Sinus Aestuum* and *Sinus Medii* and may represent an ancient, now obliterated circular impact mare.

They concluded that these velocity variations were caused by sub-surface concentrations of mass (mascons) at the approximate centres of these maria. Scientists and astronomers quickly realised the significance of this phenomenon in relation to theories of lunar, planetary and solar system formation. Subsequent analysis, confirmed by manned space flight, identified additional mascons – for a total of 12 – on the near side of the Moon.

AEROBEE 200

NASA's newest sounding rocket, carrying flight-test instruments for the 1973 Skylab project and the 1974 Orbiting Solar Observatory (OSO I), was successfully launched on 18 Jan. near White Sands, New Mexico.

The Aerobee 200, which climbed to an altitude of approximately 150 miles (240 km), contained a number of sensitive instruments designed to map X-ray radiation from the Sun's corona. By determining the precise region where X-rays originate, important information can be obtained on the nature of the Sun's atmosphere.

This type of instrumentation will be launched by rockets later this year during the Earth-orbiting Skylab mission to provide supporting data for the interpretation of high-resolution X-ray pictures taken by the large X-ray telescope on Skylab. Observation of ultraviolet and X-ray radiation from the Sun and stars – important for understanding their physical makeup – cannot be made on the Earth because of the obscuring effects of our atmosphere.

The Aerobee 200 is the latest version of the class of sounding rockets built by Aerojet Liquid Rocket Corporation.

ERTS-1 STIMULATES THIRD WORLD

'Small villages and towns are located wrongly on the maps by several tens of kilometers...Some lagoons which are shown on maps as 20 km long are in reality more than 100 km long...Large unsuspected geological features have been detected... The above excerpts from a report from Brazil are typical of communications arriving at NASA headquarters, Washington, writes Walter Froehlich. The report tells how information from the ERTS-1 satellite is helping people in other lands learn more about their country.

Looking down from its orbit at an altitude of 575 miles, the satellite is producing several thousand pictures each week and vast quantities of data about the Earth. These photographs and data are now being analysed by 300 scientists in nearly 50 nations, and distribution is continuing from the US where they are being received from ERTS-1's transmitters.

From Thailand, Dr. Pradisth Chesosakul, Secretary General of the Thai National Research Council, has written to the US space agency saying that 'the best of the (ERTS-1) scenes received are excellent; they appear to demonstrate clearly that our decision to participate in the ERTS programme from its inception was wise, and that there is much to be learned and much work to be done in order to exploit the new technology fully...'

Ghana reports that ERTS-1 information is being used in an experiment to control locusts by spotting vegetation at the edge of deserts which attracts locusts for breeding. A scientist in Iran, after studying ERTS-1 pictures and data, had reported: 'We have located several lakes which do not appear on the watershed map of Iran...In the extreme southeast part of Iran several igneous bodies have been observed which do not figure on the...geological map of Iran. By comparing (ERTS-1) images...with a map of the region...it is quite noticeable that the shape of the Bandar Shah peninsula has changed. This is possibly due to lowering of the Caspian Sea by evaporation which exceeds the inflow of stream waters'.

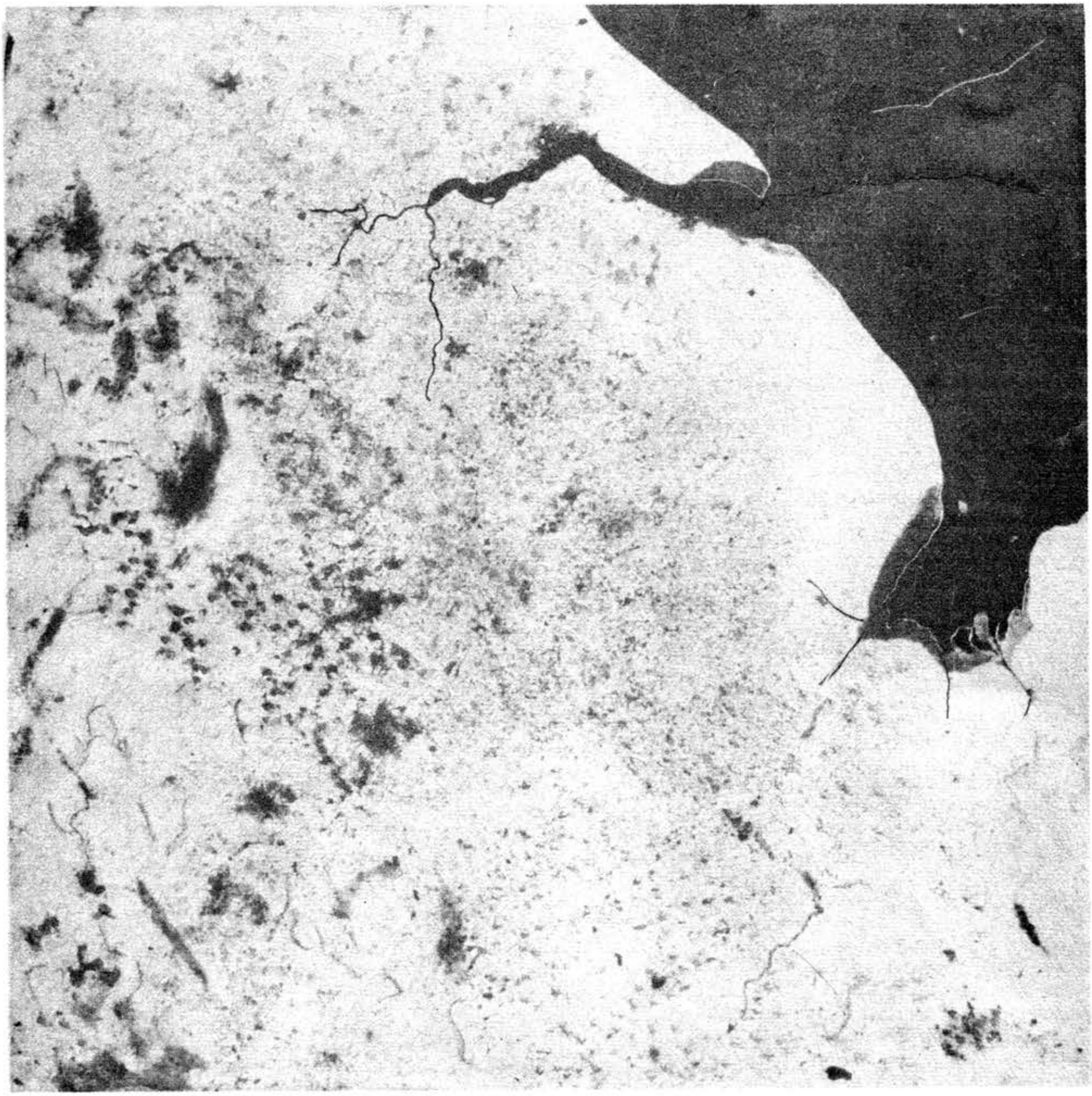
Reports from Mali indicate ERTS-1 findings are being used in making maps of remote areas, to guide water exploration efforts, and to decide routing of new roads.

Several African nations are employing space data in accordance with a recommendation made by all-African seminar in Addis Ababa that 'a complete inventory of natural resources such as water, soils, vegetation and wildlife be undertaken everywhere in Africa...[and] that the most modern techniques be used to achieve this aim, such as remote sensing through satellites'.

Dr. Fernando de Mendonca, Director General of the Brazilian Space Agency, reports that the cost of space imagery is several times less per square mile than aerial surveillance in the mapping and exploration of the Amazon region. Satellite information has shown differences in Amazon tributary positions from recent charts by as much as 20 km and 90° in direction. Islands larger than 2 sq. km were found that are not shown on present maps.

ERTS-1 orbits the Earth 14 times each day and covers the planet's entire surface every 18 days, after which it repeats its path. The satellite's photography and other sensing devices are operated only while flying over nations participating in the project. All pictures and information transmitted to Earth by ERTS-1 are available to anyone who wants them for the price of reproducing them.

To make the search for desired photographs and information easier, 19 'browse files' have been set up where scientists and



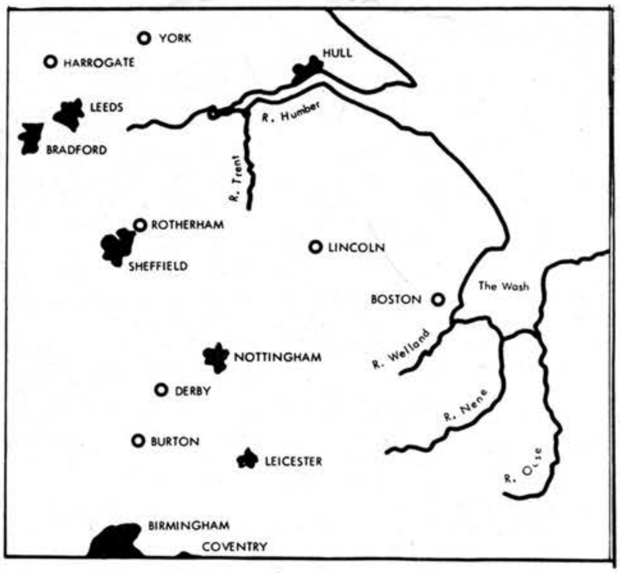
others can examine copies of ERTS-generated materials and make their selections. So far, all such 'browse' facilities are in the US. Canada has its own ERTS-1 station for reception of information and photographs directly from the satellite. The satellite stores information and photographs on tape recorders which play back their loads while passing within range of receiving stations. During its passes over the US, the satellite's instruments are turned on for the most complete space survey ever made of any nation.

In the US the satellite is checking on the growth and health of crops and forests, the relationship of vegetation to rock formations as a guide to the location of underground water, sediment distributions in lakes and estuaries (through analysis of colour tones in the pictures), sea ice distribution, snow deposits and subsequent water run-offs, and urban development for comparison with existing maps. ERTS-1 also accepts and re-transmits for collection at read-out stations the broadcasts of data from sensing instruments installed at remote locations in the US.

Some of these instruments check on water levels and the speed of river water flow. Some measure temperatures on the ground and of escaping gases on the Kilauea volcano in Hawaii, Scientists hope to find out whether these temperature changes can be used to predict volcanic eruptions.

ERTS-1 was designed to operate for a year, but on the basis of its performance during its first 6 months, engineers believe it may function much longer. Partly for that reason, the launch of a nearly identical follow-on satellite, ERTS-B,

originally scheduled for Nov. 1973, has been postponed to 1976. US astronauts flying in Skylab will carry out experiments in Earth resources observations, which may lead to improvement in techniques and equipment that could be put into ERTS-B.



Map of the east Midland region of England identifying towns and cities seen in the photograph, *left*, taken by the ERTS-1 satellite from a height of 560 miles.

United States Information Service

SPACE EYE ON BRITAIN

Remarkable pictures of Britain taken by the Earth Resources Technology Satellite from 560 miles up have been released in Washington. One shows a stretch of eastern England from the Humber to the Wash. Under a magnifier one can see the M1 motorway snaking its way through the industrial Midlands. What appears to be industrial haze hangs heavily over Sheffield. Along the east coast tidal sandbanks are clearly visible, showing large deposits of silt.

In some of the ERTS pictures, which now cover large areas of the world, resolution is good enough to identify industrial and commercial centres and highways with four and more lanes. Minor roads running through wooded areas are often visible. It has been possible to spot bridges, railways and even golf courses.

Apollo-Soyuz crew. US astronauts named for the first Apollo-Soyuz mission examine a model of the docked American and Soviet spacecraft at the Manned Spacecraft Center, Houston, Texas. From left are Donald K. (Deke) Slayton; Vance D. Brand and Thomas P. Stafford. Target launch date for the joint flight is 15 July 1975. The two crews are to visit each other's spacecraft after they have joined in Earth-orbit. Main objectives are to test equipment and techniques for international crew rescues in space and for future co-operative scientific missions.

United States Information Service

APOLLO SOYUZ RENDEZVOUS

Captain Chester M. Lee (USN, retired) has been appointed Programme Director of the US effort in the US/USSR joint manned space flight mission. As Programme Director of the Apollo Soyuz Test Project (ASTP), he will be responsible for the direction and management of the US effort in the joint mission including the spacecraft and docking module, flight and crew operations at the Manned Spacecraft Center, Houston; launch vehicle activities at the Marshall Space Flight Center, Huntsville, Alabama; and launch operations at the Kennedy Space Center.

Agreement to carry out the joint space flight was reached by President Nixon and Soviet Premier Alexei Kosygin in Moscow on 24 May 1972. The mission is scheduled to be flown in Jul. 1975.

An Apollo spacecraft and a Soviet Soyuz will dock in Earth Orbit and the crews will exchange visits. The American astronauts will be Thomas P. Stafford, Donald K. (Deke) Slayton, and Vance D. Brand. The mission is designed to test equipment for cooperative scientific missions and to establish an international crew rescue capability in space.

Prior to this assignment, Lee was Apollo Mission Director for the flights of Apollo 12 to 17. In this job, he was responsible for management, direction and coordination of mission and flight plans, schedules, and associated activities throughout NASA and other government agencies. Before joining NASA in 1965, Lee was associated with the Directorate of Research and Engineering, Office of the Secretary of Defense and the Navy Polaris programme.

CORRECTION. *We regret that two diagrams (Figs. 4 and 5) which appeared in Mr. Duncan Lunan's paper, 'Space Probe from Epsilon Böotis', in the April issue were inadvertently transposed during production. The caption which appears on page 126 refers to the diagram on page 127 and vice-versa.*

[continued on page 195

SATELLITE DIGEST — 58

A monthly listing of all known artificial satellites and spacecraft, compiled by Geoffrey Falworth. Information is based on that supplied by the Space Department of the Royal Aircraft Establishment, Farnborough, NASA, Satellite News and BIS sources. For information on the derivation of orbital parameters, abbreviations, etc., see July 1972 issue p. 262.

Continued from April issue, p. 156.

Name, designation and catalogue number	Launch date, lifetime and descent date	Shape and weight (kg)	Size (m)	Perigee height (km)	Apogee height (km)	Orbital inclination (deg.)	Nodal period (min)	Launch centre, launch vehicle and payload/launch origin
Cosmos 528 1972-87A 6162	1972 Nov 1.08 7000 years	Ellipsoid 40?	1.0 long? 0.8 dia?	1368	1470	74.03	114.21	Plesetsk USSR/USSR (1)
Cosmos 529 1972-87B 6264	1972 Nov 1.08 8000 years	Ellipsoid 40?	1.0 long? 0.8 dia?	1404	1470	74.03	114.61	Plesetsk USSR/USSR
Cosmos 530 1972-87C 6265	1972 Nov 1.08 6000 years	Ellipsoid 40?	1.0 long? 0.8 dia?	1336	1469	74.03	113.85	Plesetsk USSR/USSR
Cosmos 531 1972-87D 6266	1972 Nov 1.08 9000 years	Ellipsoid 40?	1.0 long? 0.8 dia?	1423	1471	74.03	114.83	Plesetsk USSR/USSR
Cosmos 532 1972-87E 6267	1972 Nov 1.08 4000 years	Ellipsoid 40?	1.0 long? 0.8 dia?	1302	1470	74.04	113.49	Plesetsk USSR/USSR
Cosmos 533 1972-87F 6268	1972 Nov 1.08 5000 years	Ellipsoid 40?	1.0 long? 0.8 dia?	1319	1470	74.03	113.68	Plesetsk USSR/USSR
Cosmos 534 1972-87G 6269	1972 Nov 1.08 6000 years	Ellipsoid 40?	1.0 long? 0.8 dia?	1351	1470	74.04	114.03	Plesetsk USSR/USSR
Cosmos 535 1972-87H 6270	1972 Nov 1.08 8000 years	Ellipsoid 40?	1.0 long? 0.8 dia?	1385	1471	74.04	114.42	Plesetsk USSR/USSR
Cosmos 536 1972-88A 6272	1972 Nov 3.07 8 years	Cylinder + vanes?	2 long? 1 dia?	518	544	74.02	95.27	Plesetsk USSR/USSR
 1972-89A 6275	1972 Nov 9.21 80 years	Polyhedral cylinder 275	2 long? 0.5 dia	813	872	98.65	101.80	WTR Thor Burner 2 DoD/USAF
Telesat 1 1972-90A 6278	1972 Nov 9.95 10^6 years	Cylinder + antenna 294.84	1.52 long 1.88 dia	35822 35780	36508 35791	0.4 0.1	1455.5 1436.0	ETR LC 17B Delta Telesat Canada/NASA (2)
Explorer 48 1972-91A 6282	1972 Nov 16.93 9 years	Domed cylinder + 4 panels 185.98	1.29 long 0.55 dia	444	632	1.90	95.20	SMLC Scout C NASA/NASA (3)
Esro 4 1972-92A 6285	1972 Nov 22.01 18 months	Cylinder + 4 booms 113.30	0.90 long 0.76 dia	245	1173	91.11	99.00	WTR SLC 5 Scout D ESRO/NASA (4)
Cosmos 537 1972-93A 6287	1972 Nov 25.38 11.8 days (R) 1972 Dec 7.2	Sphere-cylinder 4000?	5 long? 2.44 dia	204	305	64.95	89.59	Plesetsk USSR/USSR (5)
Intercosmos 8 1972-94A 6291	1972 Nov 30.91 4 months	Domed cylinder + 6 panels 400?	1.8 long? 1.2 dia?	204	649	71.01	93.11	Plesetsk Cosmos USSR/USSR (6)

Supplementary Notes:

(1) Fifth Soviet eight-payload satellite launch, 12th Cosmos multi-payload mission and 15th Soviet multiple-satellite flight.

(2) Telesat A, first in a series of Canadian domestic communications satellites designed to act as a spaceborne communications repeater capable of receiving transmissions from Earth stations for

retransmission to Canadian Earth stations provides an interim operational Canadian satellite communications capability, distributes network TV to major southern Canadian centres for further distribution by ground-based systems and to remote Canadian centres for local rebroadcasting, heavy-route message traffic between large population centres to supplement existing terrestrial systems and small group message services between northern Canadian centres and between northern and southern centres. Spacecraft structure comprises a 0.76-metre diameter thin-walled central cylindrical structure surmounting the satellite's integral solid-propellent orbital injection rocket motor supporting a 1.85-metres diameter electronics platform, itself supporting the cylindrical solar cell array at its periphery. Power supplies of 250 watts nominal during the spacecraft's estimated 7 years' active on-orbit lifetime are maintained by 20448 negative-on-positive, 2-cm square, silicon solar cells located on panels surrounding the spacecraft's cylindrical structure which also recharge two onboard nickel cadmium battery systems, comprising four separate 7-cell packs, used during pre-launch, launch to spacecraft-separation, transfer orbit coast and two annual 46-days' long eclipse periods occurring during summer and winter solstices. Redundant Sun- and Earth-sensors, the latter comprising 15-micron infrared wavelength-sensitive bolometer detectors and telescope mounted video amplifiers aligned 5° north and south of Telesat 1's equatorial plane being 45° apart around the spacecraft's cylindrical outer structure beneath Telesat 1's internal electronics equipment panel, provide spacecraft attitude data to Earth permitting determination of antenna azimuth orientation by comparing Sun- and Earth-sensor acquisition pulses and onboard antenna reference pulse. Telesat 1's spin-phase angle is determined from Sun-sensor signal output suitably adjusted for propagation delay, while spacecraft spin axis is determined from both Sun- and Earth-sensor pulses. Attitude control and orbital location system uses two 45-kg hydrazine gas jet thrusters, each system utilising two titanium hydrazine tanks each mounted on opposite quadrants of the spacecraft's 0.76-metre diameter central thrust tube holding Telesat 1's apogee motor supplying four gas jet thrusters mounted inboard on the cylindrical solar array's aft section, two gas jet nozzles aligned to fire parallel to the spacecraft spin axis controlling Telesat 1's orbital inclination by long-duration thrusting and orientation by intermittent pulsing and remaining two gas jet nozzles pulse-fired through the spacecraft's average centre of gravity fine-controlling Telesat 1's orbital period and orbital eccentricity, and maintains Telesat 1, spin-stabilised at 100 rpm with a mechanically-despun, constantly Earth-oriented communications antenna utilising a radio-frequency rotating joint conducting signals from the rotating electronics platform to the despun antenna feed system, within ±64 km of its internationally-approved and co-ordinated equatorial geostationary orbital location at longitude 109° West to within $\pm 0^\circ.1$ in longitude and $\pm 0^\circ.1$ in orbital inclination. Onboard communications system provides twelve all-microwave fixed-gain multiplexed repeater channels each having a useable bandwidth of 36 MHz, centre-to-centre spacing between adjacent channels being 40 MHz leaving a 4-MHz guard band, and each having a 960 one-way voice or single colour TV channel capability, 10 carrying communications traffic and two acting as backup or reserve channels, Telesat 1 receiving transmissions in the 5.925- to 6.425-GHz band an retransmitting in the 3.7- to 4.2-GHz band throug all-microwave chanelised communications repeater utilising light-weight 20-mil Invar waveguide filters and 12-high-efficiency 5-watt travelling wave tubes, amplitude and phase equalisation being performed at ground stations, through an onboard 1.52-metres diameter parabolic antenna mounted on top of the spacecraft structure covered with fine metal optically-transparent mesh for alleviating solar pressure perturbations while allowing acceptable satellite precession rate at orbital altitudes, fed by spacecraft-structure mounted three-horn feed assembly accommodation reception and transmission which, being horizontally aligned, provide a 3° by 8° beamwidth antenna pattern wider in the horizontal plane, pattern shape being determined by horn feed centre separation, transmission feed assembly comprising two feed horns and reception feed assembly comprising three feed horns and a sub-reflector. Offset parabolic antenna tilted $7^\circ.85$ northwards provides maximum audibility to Canada and also supports toroidal beam command and telemetry antenna used during transfer orbit coast to apogee, onboard communications frequency bands also accommodating telemetry, tracking and spacecraft command transmissions. Spacecraft operation and commands are activated by Telesat Satellite Control Centre, Ottawa through its main tracking, transmission and data reception antenna at Allan Park, Ontario, Telesat's initial ground station system comprising about 37 Canadian-built stations including heavy-route stations at Allan Park and Cowichan working Telesat 1 through 30-metre diameter antennae capable of handling all telecommunications, network TV stations at St. Johns, Halifax, Montreal, Winnipeg, Regina and Edmonton used for regional distribution of network programming and transmission and reception of TV signals, 25 remote TV stations at Clinton Creek, Dawson, Elsa, Whitehorse, Faro, Watson Lake, Cassiar, Fort Nelson, Norman Wells, Fort Good Hope, Inuvik, Yellowknife, Pine Point, Fort Smith, Uranium City, La Ronge, Sept-Iles, Churchill, Great Whale, Fort Chino, Fort George, Goose Bay, Port au Port and Magdalen Islands equipped to receive TV programmes, and two northern telecommunication Earth stations providing two-way telephone, TV and radio signals for rebroadcasting at Frobisher Bay and Resolute, and two thin-route stations to provide telephone service and radio rebroadcast capability to small remote Arctic communities at Pangnirtung and Igloolik. Following nominal launch by the three-stage Thrust Augmented Thor Delta launch vehicle using nine solid-propellent thrust-augmentation rocket motors, six of which ignited at launch and the remaining three at 39 seconds into the mission, Delta's second stage (1972-90B) ignited at about 4 min. 31 sec. after launch placing the vehicle in a low parking orbit while, about 19 minutes later, Delta's third stage and attached spacecraft, spun-up utilising small spin table-mounted solid propellent rocket motors, separated and injected itself and the spacecraft into an elliptical transfer orbit. Third stage burnout about 24 min. after launch was followed by spacecraft separation using a rocket-mounted spring-separation system and, on Telesat 1's seventh apogee, about four days after launch, the spacecraft's onboard, integral, solid-propellent rocket motor fired for about 42 sec. imparting a velocity increase of about 1.85 km per sec. to circularise the spacecraft's equatorial geostationery orbit. Telesat 1 was allowed to drift eastwards around the equator at about 3° per day and onboard attitude control system gas jets fired during 1972 Nov 25 to place the spacecraft in its nominal on-orbit location. Orbital data at 1972 Dec. 1.0 and 1973 Jan 1.0.

(3) SAS B, second Small Astronomy Satellite, obtains celestial gamma radiation source and flux data from a low-inclination, low-altitude Earth orbit, measures galactic and extragalactic diffuse gamma radiation dependance to within $\pm 1^\circ$ at 100 MeV and over energies, measures gamma radiation energy spectra as a function of direction between 25 and 200 MeV and integral intensity above 200 MeV, determine galactic and extragalactic discrete gamma radiation sources and their existence, location, intensity and energy spectra, observes supernovae-originating short-burst gamma radiation and observes pulsar-originating gamma radiation. Explorer 48's cylindrical 0.61-metre long, 0.55-metre diameter control section, capable of carrying and supporting mission-dependent interchangeable experimentation, consists of an aluminium outer structure containing attitude and stabilisation control systems, data storage systems, power storage and regulation systems, tape recorder and digital science and engineering telemetry transmitting in PCM/PM VHF real-time or on command at 136.080 MHz at 0.25 watt through two solar panel-mounted telemetry transmission antennae with additional tracking beacon telemetry being transmitted at 136.680 MHz and recorded data being transmitted at 136.680 MHz at 1.5 watts. Telemetry is received at Explorer 48's prime ground station at Quito in NASA's Space Tracking and Data Acquisition Network augmented by other NASA equatorial tracking stations as required. Explorer 48 continuously transmits experiment and engineering data while onboard tape recorder records data simultaneously for later transmission at 20 times recorded speed once per orbit to Quito which also transmits up to 60 commands per orbit relayed from NASA Goddard SFC to Explorer 48. Power supplies of 27 watts nominal are maintained by four 1.45-metres long, 0.26-metre diameter panels holding negative-on-positive silicon solar cells recharging onboard nickel cadmium batteries folded against Explorer 48 during launch and deployed perpendicular to the spacecraft's control section after orbital insertion. Spacecraft stabilisation and

experiment-required rotation are maintained for separate systems for spin-axis orientation and spin-rate control using an internal stabilising rotor system providing adequate angular momentum for nominal gyrostabilisation, a nutation damper, star sensors and chargeable trim electromagnet controlling spin rate which, in conjunction with Earth-based computers defining onboard magnet energisation point, utilises Earth's magnetic field to align the spacecraft, attitude being determined to within ±3° and orientation to within 0°.25 in support of experimentation data. Explorer 48's onboard experimentation uses a control section-mounted digitised spark chamber gamma ray telescope, an advanced version of similar high-altitude balloon experimentation, incorporating a 32-deck upper digitised spark chamber, scintillator, lower spark chamber, four-unit Cerenkov counter assembly, light pipes connecting spark chamber-mounted scintillator with four internal photomultipliers, and associated electronics and mounting systems enclosed in a domed, cylindrical pressure vessel. Incoming gamma radiation produces electron pairs in one of the thin plates located between the spark chamber decks, subsequent analysis of gamma radiation tracks permitting three-dimensional trajectories of gamma ray particles to be determined. Spark chamber detector's outer dome covering discriminates against charged particles and ancillary radiation counters determine times of spark chamber pulse and data readout. Experimentation, capable of determining gamma ray arrival directions to within ±1° and measuring energy spectra between 25 and 200 MeV and total energy flux above 200 MeV is aligned along Explorer 48's main spacecraft axis, gamma radiation arrival directions and energies being determined directly from spark chamber track analysis. Following nominal launch, Scout C's solid-propellent fourth-stage motor fired about 10 minutes after launch and between three and six minutes later onboard adapter-mounted timers fired a pyrotechnic cable-cutter releasing two despin weights and cables and permitting Explorer 48's solar panels to deploy and reducing spin rate from 137 rpm to about 5 rpm. About 3 min after despin weight jettison, fourth stage adapter-mounted timers fired separation clamp bolt cutters releasing the spacecraft from the Scout C fourth stage (1972-91B) while three helical adapter-mounted springs pushed Explorer 48 away from the fourth stage at about 1 metre per sec. Following spacecraft engineering test and onboard experimentation and equipment checkout procedures, Explorer 48 experimentation was activated on 1972 Nov 27; preliminary telemetry indicates that all systems are operating nominally.

(4) Eighth European Space Research Organisation spacecraft and seventh to attain orbit investigates and measures northern polar ionospheric phenomena for correlation with ground-based ionospheric measurements and simultaneously-acquired data from sounding rockets launched from Kiruna, Sweden, during selected spacecraft passes, studies neutral and ionised particle species in Earth's ionosphere and near magnetosphere, measures auroral particle flux energy and pitch-angle distribution and monitor solar particle flux during solar active periods in studies of particle penetration and diffusion in Earth's magnetosphere for correlation with other satellite data during its nominal 1.5 years' active lifetime. Power supplies of 65 watts nominal for spacecraft systems operation and onboard 20-cell, 6 ampere-hour nickel cadmium battery recharge capability are maintained by 6990 negative-on-positive silicon solar cells mounted on three cylindrical honeycomb substrate panels forming Esro 4's outer cylindrical structure; power during eclipse and peak requirement periods is maintained by the battery system while storage capacitor supplies additional power as required during sunlit transits. Spacecraft, comprising vertical central thrust-tube holding two circular horizontal honeycomb equipment-mounting platforms surrounded by the three cylindrical solar panels and upper and lower thermal shields, is spin-stabilised at between 60 and 75 rpm initially by launch vehicle's pre-injection spin-stabilisation while three centrifugally-deployed, rigid, 1.40-metres long booms, one carrying onboard positive ion spectrometer and two carrying dummy masses for nominal spin-stabilisation and spacecraft balance, radially deployed automatically following spacecraft separation, maintain nominal 65- to 70-rpm spin rate. Fourth 0.35-metre long positive ion spectrometer boom is deployed axially opposite to the Sun vector using an internal spacer system. Attitude control and nominal spacecraft orientation is maintained by inherent spin stabilisation and measured by outward-viewing, 120°-field of view digital solar aspect sensor and three-axis magnetometer, while attitude manoeuvres are performed using internal magnetotorquer polarity reversals each quarter orbit creating required torque for attitude re-orientation. Esro 4's quarter-orbit polarity switching techniques permit frequent real-time spin-axis re-orientation providing optimum spacecraft and instrumentation orbital operating conditions, five pre-planned standard spacecraft attitudes being used according to operational, power availability and experimental constraints Nominal onboard operational thermal control is maintained by upper and lower instrumentation area-enclosing thermal covers and mid-section experimentation viewing area thermal control. Solar aspect offset, the angle between the Sun vector and the plane normal to Esro 4's spin axis, upper limit of 44° during normal operations and manoeuvres prevents solar overheating of spacecraft components. Spacecraft's split-phase telemetry system multiplexes scientific and engineering data and, using two transmitters operating at same carrier frequencies for transmission of continuous low-speed, 640-bits per sec, real-time data also utilised for spacecraft tracking, or intermittent ground-commanded, 20480-bits per sec. tape-recorded data, transmits at 137.200 MHz at 0.3 watt, and transmission of high-speed real-time data or low-speed real-time plus tape-recorded playback data at 137.200 MHz at 2.8 watts, through four telemetry rod antennae extending from Esro 4's base, to ESRO stations operating through primary control stations of European Space Operations Centre, Darmstadt and Redu, Ny Alesund, Fairbanks, Port Stanley, Tromso and NASA's Tananarive ground stations together with additional limited tracking and data acquisition support as required from NASA's Space Tracking and Data Acquisition Network and Centre National d'Etudes Spatiales tracking stations. Esro 4's onboard telecommand receiver system, compatible with NASA's tone-digital command standard, receives at 128.25 MHz, demodulates and decodes ground-transmitted spacecraft commands. Spacecraft operations subsystem performs signal conditioning for 10 spacecraft temperature channels, multiple-channel command amplification and radial boom, axial boom and neutral mass spectrometer protective cover (1972-92C) pyrotechnic ejection systems. Power subsystem also contains logic circuits measuring battery charge state, sunlight and eclipse spacecraft operation and voltage current protection. Esro 4's onboard experimentation includes a spherical, boom extremity-mounted, 360°-viewing angle, positive ion spectrometer from University College London's Mullard Space Science Laboratory surrounded by a grid maintained at negative potential repelling electrons, boom-mounted, box-shaped Langmuir probe sweeping space potential to determine energy scale zero baseline in support of spherical probe's measurements and to acquire data on electron temperatures and densities, and third spherical axial boom-mounted spectrometer monitoring total ion density, measures energy distribution and drift velocity, total ion density and its irregularities and electron temperature and density at orbital altitudes; experiment, requiring minimum 5000-sq cm conducting area provided by two additional radial boom-mounted spherical masses, performs mass scan cycle each 4.8 sec, while spacecraft's solar cell panels have their positive sides earthed to maintain satellite's electrical potential. Upper experiment shelf-mounted monopole-type. 180°-viewing angle neutral mass spectrometer from Physikdisches Institut der Universitat Bonn using a radiofrequency analysing field investigates upper thermospheric and exospheric neutral gas composition and total mass density in Earth's ionospheric F-region between 300 km and 750 km by measuring neutral particles ionised by upper instrumentation-mounted hot filament prior to collection by an electrometer and venetian blind-type electron multiplier; analyser radio frequency covers mass range between 1 and 44 atomic mass units in 16 steps, composition scale origin is frequently checked, spacecraft's surfaces next to the experimentation's spectrometer are sealed to prevent outgassing in orbit and internal system drifts can be corrected by ground commands. Auroral particle spectrometer from Kiruna Geofysiska Observatorium mounted on Esro 4's lower experimentation bay and having a 40°-viewing angle, investigates auroral zone low-energy particle precipitation mechanisms by monitoring particle pitch-angle distributions and 0.5 keV- to 150 keV-energy range proton and electron flux using channel multipliers viewing radially outwards with a 15° by 60°-viewing angle from Esro 4's experimentation mid-

section and axially from the spacecraft's base with a 15° by 60°-viewing angle detecting protons and electrons between 0.15 keV and 15 keV and electrons between 0.1 keV and 0.3 keV; two Geiger counters monitor electrons with energies greater than 40 keV and three solid-state detectors count protons and electrons between 50 keV and 150 keV, measurements being subsequently correlated with ground-based and sounding rocket auroral observations. Esro 4's solar particle spectrometer from Laboratorium voor Ruimteonderzoek, Sterrekundig Institut, Utrecht, comprising two solid-state detector telescopes, one using three surface-barrier detectors measuring protons and alpha particles between 2 MeV and 15 MeV over an 80°-viewing angle and second telescope analysing protons and alpha particles in three ranges between 15 MeV and 100 MeV using three solid-state detectors and fourth solid-state anticoincidence detector over an 80°-vewing angle, observe outwards through Esro 4's upper thermal shield to investigate polar cap absorption events and interplanetary propagation and magnetospheric entry mechanisms of solar high-energy particles; activated each half-orbit during either north-or south-polar transits depending on spacecraft attitude, telescopes view space 25° from satellite spin axis minimising counting rate effects of varying spin axis-magnetic vector angles. Solar flare particle flux and energy spectra, lower Van Allen belt trapped particles and galactic and non-solar energetic particles are measured by two base-mounted, 48°- and 50°-viewing angle telescopes and associated upper shelf-mounted electronics from Max Planck Institut fur Extraterrestrische Physik, Garching, first telescope utilising two silicon surface barrier detectors mounted below a 45°-viewing half-angle tantalum collimator incorporating a 1.2 kilogauss magnet preventing low-energy electron impingement, measuring protons between 0.2 MeV and 1.3 MeV and alpha particles between 2.5 MeV and 8 MeV; second 30°-half angle sensitivity-cone telescope comprises stack of two solid-state detectors mounted above a cesium iodide scintillator, light emitted by which is collected by two light-sensitive diodes, surrounded by a plastic scintillator viewed by a phototube, measuring protons between 1.3 MeV and 90 MeV and alpha particles between 9.5 MeV and 360 MeV. Onboard horizon crossing indicator from ESRO's European Space Research and Technology Centre, Noordwijk flight tests infrared horizon sensing instrumentation for future spin-stabilised spacecraft attitude measurement and control systems; indicator measures location and time of horizon transit each orbit using internally-mounted instrumentation. Nominal launch was followed by the Scout D launch vehicle's solid-propellent Altair III fourth stage rocket motor ignition about 6 minutes later following which the spacecraft entered a near-polar, eccentric, retrograde, geocentric orbit 35 seconds later. Esro 4's three radial experiment and stabilisation booms deployed nominally about 7 min. 35 sec. after launch as the spacecraft passed over Tananarive and injection spin rate of 145.3 rpm was subsequently decreased to near-nominal values following spacecraft separation from the fourth stage (1972-92B) nearly 11 min. after launch. Initial engineering and experimentation telemetry from the spacecraft indicated that all onboard systems were operating nominally with satellite spin rate and solar aspect angle being near expected pre-launch values.

(5) Transmitted at 19.995 MHz.

(6) 10th Soviet co-operative satellite in which research institutions and observatories in Bulgaria, Czechoslovakia, German Democratic Republic, Hungary, Poland, Rumania and the Soviet Union provided equipment and observations, continues global studies of Earth's ionospheric characteristics initiated by Intercosmos 2 (1969-110A). Onboard instrumentation supplied by institutions in Bulgaria, Czechoslovakia, German Democratic Republic and Soviet Union measures electron and positive ion concentrations surrounding the spacecraft at orbital altitudes using electronic elements and an ion trap supplied by Bulgaria, electron temperatures and electron integral concentrations between Intercosmos 8 and Earth using Czechoslovak electronic instrumentation and flux of electrons with energies over 40 keV and protons with energies over 1 MeV. Intercosmos 8's high-inclination orbit enables the spacecraft to traverse Earth's high-latitude ionosphere, auroral region and geomagnetic pole. Preliminary telemetry, incorporating a German Democratic Republic high data-rate telemetry subsystem and two-frequency telemetry transmitter operating at 20.0045 MHz and 30.0065 MHz, indicated that all onboard instrumentation was operating nominally.

Decays:
Operations 8285, 1969-65A, decayed 1973 Jan 4, lifetime 1253 days.

Amendments:
Cosmos 248, 1968-90A, weight is 1400?
Peole 1, 1970-109A, lifetime is 20 years, perigee is 517, apogee is 747, period is 97.17.
Cosmos 440, 1971-79A, lifetime is 401.18 days, descent date is 1972 Oct 29.62.
Cosmos 496, 1972-45A, shape is Sphere-cylinder + domed cylinder + 2 panels + antenna, weight is 6500?
Cosmos 510, 1972-72A, third orbit perigee is 750, apogee is 39470, inclination is 62.89, period is 715.02. Amend Supplementary Note (3) to read: Orbital data at 1972 Sep 20.0, Oct 1.0 and Dec 30.7.
1972-83C, lifetime is 14.47 days, descent date is 1972 Nov 1.97.

Space Report*/continued from page 191]*

MAPPING THE SOUTHERN SKY

An international team of astronomers will soon begin to map the entire sky in the southern hemisphere using photographic plates supplied by Eastman Kodak. The survey will be published in atlas form and distributed to observatories and universities around the world.

'Basically, the project is designed to find out just what is in the southern sky', explains Dr. Vincent Reddish of the Royal Observatory, Edinburgh. 'The northern sky was mapped in the 1950's but no atlas of the southern sky exists. Once we know what's there, astronomers around the world can turn their attention to the most interesting objects.

We expect to discover many objects similar to those turned up by the northern survey – asteroids, comets and planetary nebulae. We're particularly interested in pinpointing quasars (quasi-stellar objects), mysterious X-ray sources, and objects which have been detected by radio telescopes but have yet to be identified photographically'.

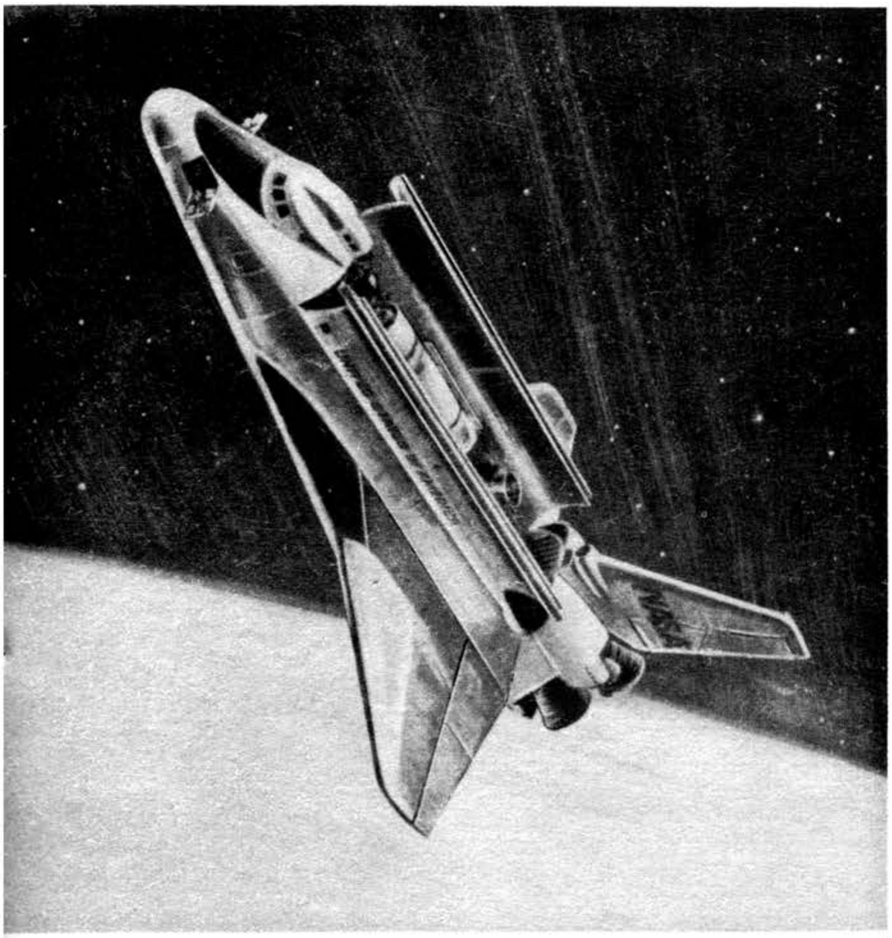
Dr. Reddish and two other colleagues visited Eastman Kodak in Rochester, New York, recently to discuss the availability of special photographic plates, new emulsions and materials for duplicating plate images. About 1,800 plates – primarily Kodak Spectroscopic Plates, Type Ha-O and Type IIIa-J together with Kodak Special Plates, Type 098-04 – will be needed to map the sky, while 200,000 to 400,000 photographic copies will be used in compiling the atlas. The project will take several years.

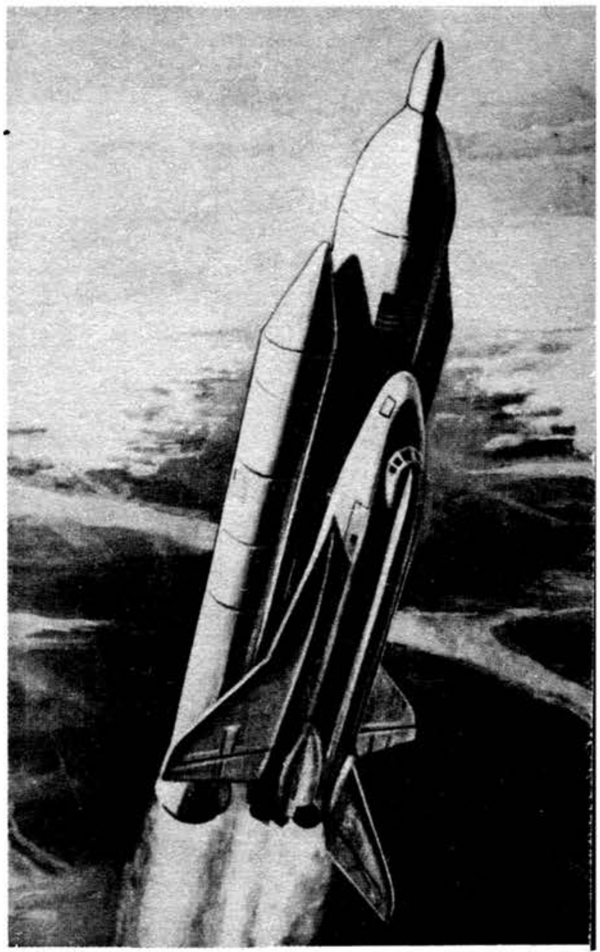
The survey is a co-operative venture of Britain's Science Research Council (SRC) and the European Southern Observatories (ESO) – an organisation supported by Belgium, Denmark, France, Germany, the Netherlands and Sweden. The ESO observatory for the southern sky project is located in Chile while SRC is now constructing its observatory in Australia. Reddish and his colleagues – Dr. Richard West of ESO-Switzerland and Mr. Hans-Emil Schuster of ESO-Chile – have decided to photograph each section of the southern sky on different emulsions to acquire ultraviolet, blue, red, infrared and limiting magnitude surveys. Different emulsions are needed to photograph the entire content of the sky because stars emit light at different wavelengths. The limiting magnitude survey will detect faint or more distant stars.

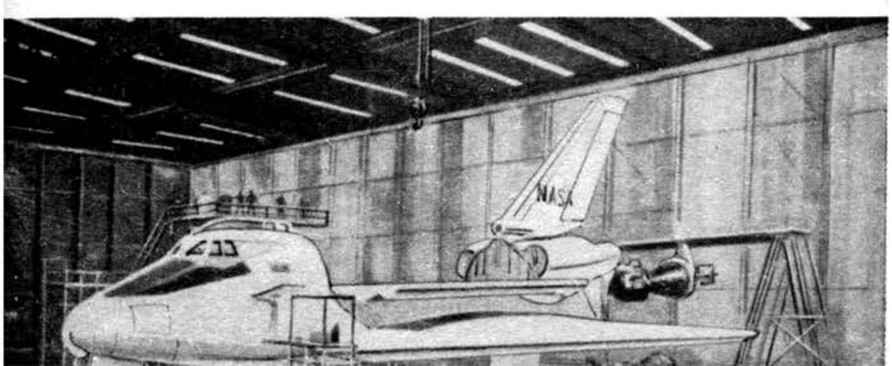
SPACEFLIGHT

88905 КОСМИЧЕСКИЕ ПОЛЕТЫ № Т–6
(спейсфлайт)
По подписке 1973 г.

Volume 15 No. 6 June 1973







SPACEFLIGHT

A Publication of The British Interplanetary Society

VOLUME 15 NO 6 JUNE 1973 *Published 15 May 1973*

Editor:
Kenneth W. Gatland, FRAS, FBIS

Assistant Editor:
L. J. Carter, ACIS, FBIS

CONTENTS

COVER

DC-3 OF SPACE. These pictures show the latest configuration of the NASA space shuttle being developed by the space division of Rockwell International. The contract for the orbiter's large expendable tank is expected to be placed in August; that for the Solid Rocket Boosters in November. *Left,* payload doors of the orbiter open in space to release scientific satellite. Note that the wings now have a double-delta geometry. *Right,* with all engines firing the shuttle streaks spaceward from Cape Kennedy in an initial test flight planned for 1979. *Below,* quick turn-around is essential to the design. Maximum emphasis is being placed on achieving rapid and easy maintenance, returning the vehicle to flight status within 2 weeks. The first part of a major feature on the 'Evolution of the Space Shuttle' begins on page 202.

Rockwell International's Space Division

MILESTONES

Mar

14 - 15 After a period of research along the south-eastern rim of Le Monnier crater, Lunokhod 2 moves in a north-easterly direction to measure physical, mechanical, chemical and magnetic properties of lunar rock. Total distance covered since 16 January is 17,680 metres.

17 - 18 Lunokhod 2 travels 5,364 metres in region of numerous craters and scattered boulders.

19 Lunokhod 2 approaches 16 km long by 300 metres wide tectonic fracture running north-to-south in the south-eastern part of Le Monnier crater.

25 Lunokhod 2 ends third lunar day of activity having covered a total distance of 25.6 km. Studies include examination of crater which has traces of 'sliding of soil on its slopes'.

Apl

2 NASA issues 'request for proposals' to US industry (Boeing, Chrysler, Martin Marietta, McDonnell Douglas) for design, development and production of Space Shuttle's 158 ft. x 27 ft. diameter external tank which will contain 1.5 million lb. of Lox/LH_2 propellents.

3 Soviets launch Salyut 2 orbital scientific station by Proton rocket from Baikonur at about 9 a.m. GMT 'to perfect the design of on-board systems and equipment and for conducting scientific and technical research and experiments in space flight'. Orbit is 215 - 260 km inclined at 51.6 deg. to equator; period 89 min.

4 Soviet mission control manouvres Salyut 2 upward to achieve more stable orbit of 239 - 261 km. U.S. tracking network detects 23 fragments which could have come from the separated carrier rocket.

4 NASA confirms that Skylab is scheduled for launching from Kennedy Space Center on 14 May at 1.30 p.m. EDT; first 3-man crew to be launched no earlier than 1. p.m. EDT 15 May.

5 NASA launches 570 lb. Pioneer 11 by Atlas-Centaur AC-30 from Cape Kennedy on second fly-by mission to Jupiter.

8 Soviet mission control changes orbit of Salyut 2 to 261 - 286 km inclined at 51.55 deg. to equator, according to Western tracking sources.

9 BAC reveals that Concorde 001 will be used to make an 80-min observation of solar eclipse on 30 June flying at over 1,000 m.p.h. at 60,000 ft. in shadow of Moon across central Africa.

9 Lunokhod 2 is re-activated at beginning of new lunar day. Temperature within instrument compartment is 18°C and pressure 773 mm of mercury.

11 Salyut 2 completes 130 orbits of Earth – according to *Tass* – with 'on-board systems and instruments functioning normally'. Orbit is 261 - 296 km, inclination 51.6 deg.

16 Skylab SL-1 on 2-stage Saturn V transported from Vehicle Assembly Building to Launch Complex 39A at Kennedy Space Center, Florida.

В журнале не печатается ряд страниц.

EVOLUTION OF THE SPACE SHUTTLE

PART - 1

By David Baker

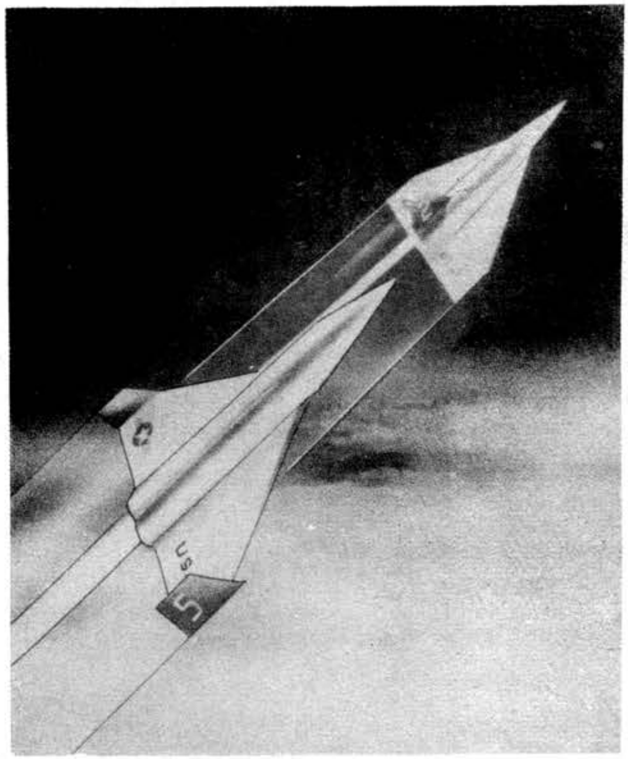
The re-usable Space Shuttle has a long and varied history. Its broad principles were laid down before World War 2 by the Austrian astronautical pioneer Dr. Eugen Sänger, whilst schemes to produce long-range winged rockets at Peenemünde also focussed attention on basic engineering problems.

A starting point for the two-stage piggy-back winged orbiter/booster configuration was the celebrated 'Dornberger Project' carried out whilst Dr. Walter Dornberger, the former commandant at Peenemünde, was a consultant to Bell Aircraft Company after the War. Our own Society placed considerable emphasis on winged shuttles in studies dating from the late 'Forties, and looking back 25 years it interesting to compare the original conceptual drawings by the late Ralph Smith with modern space shuttle designs. Dr. Wernher von Braun himself contributed to the concept of large re-usable boosters in a well-remembered series of articles on the Space Future which appeared in *'Colliers'* magazine in 1952.

Since that time many aerospace companies in the United States and Europe have made detailed studies of the concept, some privately and others supported by Goverment study contracts. One practical outcome was the USAF/Boeing X-20 Dyna-Soar cancelled in 1963; but only comparatively recently has technology really become equal to the task of creating practical hardware for the Earth-to-orbit ferry role.

This article examines the generic progress of the Space Shuttle after NASA began to apply emphasis to the concept four years ago.

Kenneth W. Gatland.



The celebrated 'Dornberger Project' which introduced the piggyback concept of a recoverable launch system to the United States. The study was made by Bell Aircraft Company under the direction of Dr. Walter Dornberger shortly after World War II.

J. W. Wood

Throughout 1968 NASA consolidated its thinking on future programmes, objectives, and national requirements. Early that year, on 28 Feb. George Mueller, Associate Administrator for Manned Space Flight, had testified before the Senate Space Committee and stressed the importance of a new approach to space logistics.

Mueller was to formulate plans for a system of manned orbital bases, nuclear rockets for translunar and interplanetary journeys, and orbit-to-orbit propulsion systems for shunting heavy payloads into different orbits. All of this activity would generate a considerable amount of traffic and between 30,000 and 40,000 lb. of cargo would need to go aloft every month. This made it more important than ever to find a cheaper way to deliver than via a one-way ticket to orbit, and in any case, regular crew rotation would demand a two-way vehicle.

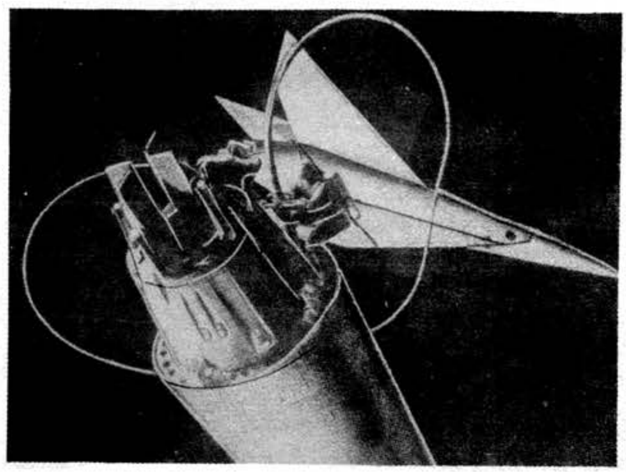
On 10 Aug. 1968, George Mueller came to London to address the British Interplanetary Society and for the first time publicly displayed NASA interest in a re-usable transport system. Announcing the preliminary results of in-house studies he advised his enthusiastic audience that NASA currently favoured the single-stage design with external propellent tanks.

Just how serious NASA was about the Shuttle became evident on 31 Jan. 1969 when four industrial contractors were appointed to study varying approaches to the design of a vehicle, at that time called the ILRV (Integrated Launch and Re-entry Vehicle). General Dynamics and Lockheed were answerable to the Marshall Space Flight Center; McDonnell Douglas to the Langley Research Center, and North American Rockwell to the Manned Spacecraft Center. Each contract was worth $500.000. These phase A feasibility studies were to run until Sep. 1969 when NASA would gather together the results and conduct an appraisal of the designs.

At about this time NASA began a study at the Manned

Recoverable winged shuttles were also part of early post-War studies by the British Interplanetary Society. This classic painting by the late R. A. Smith (circa 1948) shows astronauts connecting a flexible hose to the fuel valve of a tanker rocket in Earth orbit.

British Interplanetary Society



Spacecraft Center of the two-stage fully re-usable concept and this approach undoubtedly influenced North American Rockwell in its own design emphasis. By Jul. the ILRV contracts were re-oriented toward this two-stage approach. It was 1 Nov. before these Phase A studies had been completed, emphasising the fully re-usable concept and pointing NASA firmly in that direction.

By Apr. of that year a Space Shuttle Task Group had been formed at Administrative headquarters in Washington.

In the three months following conclusion of the Phase A ILRV study NASA evaluated the requirements and matched these to the industrial studies, cementing its conviction that the two-stage fully re-usable vehicle would satisfy demand. On 18 Feb. 1970, the Request For Proposals (RFP) were issued from Washington. Industry was asked to bid for Phase B definition studies, and proposals were submitted on 30 Mar. Strong elements of the aerospace industry combined interests to form co-operative amalgams that would heavily influence NASA selection. Boeing joined with Lockheed, McDonnell Douglas teamed with Martin, Pan American Aviation and TRW, leaving North American Rockwell to select last.

Following a period of deliberation North American Rockwell's Space Division and McDonnell Douglas were chosen on 12 May 1970 to proceed, on 1 Jul. to a Phase B definition of the two-stage, fully re-usable, fly-back Shuttle.

Shortly after NR and MDC began their work pressures from dissident minority groups within the NASA organisation managed to commit further funds to alternative approaches to Shuttle design, which led to further Phase A awards to Grumman/Boeing, Lockheed, and Chrysler. This resulted in various less promising concepts but from the work of the Grumman/Boeing team came a steering influence on the whole concept, affecting not only the smaller contract studies but the design philosophies of both NR and MDC. The results were major programme changes and eventually the Shuttle was transformed into a very different vehicle from the one considered at the outset of Phase B.

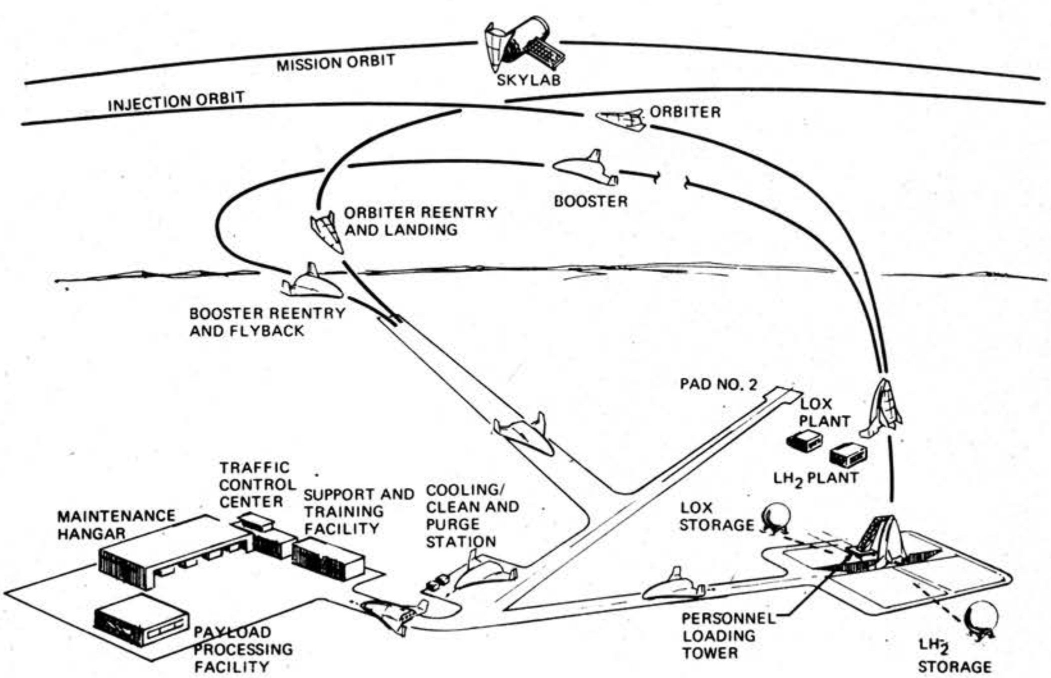
1. Design Objectives

The design that North American Rockwell had submitted during the first half of 1970 was a radical departure from the original concept and would ultimately prove to be but a progenitor of many other variants that two years later would win for the Space Division the coveted prize of prime contractor.

The baseline design that had emerged was a contemporary of the single launch space stations era. The design reflected this emphasis. It became evident that the fully reusable, manned booster would exhibit very low launch costs, an important factor where heavy logistical haulage work is a major item on the flight schedule. However, the price to be paid would be a development cost that would ultimately be cut by 60% before a tolerable budget could be reconciled with a working design.

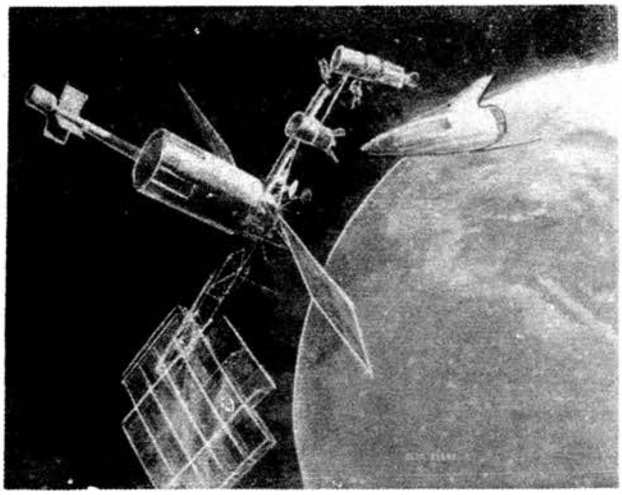
As the Space Division went into the definition phase these costing values were ill-defined with emphasis being placed more on the technical viability than design economics.

A major partner with NR at that time was the General Dynamics Convair Division, emphasising the manned booster and possessing prime responsibility for this element of the Shuttle. IBM were heavily committed to NR on data management systems and worked with the Space Division to prepare analyses of the different approaches interfacing the avionics. Honeywell Incorporated were responsible for the vehicle guidance control systems, working in conjunction with IBM.



At last – in the late 1960's – the space shuttle begins to take realistic form in America. The Boeing drawing released in 1969 shows the possible arrangement for a shuttle ground handling facility.

The Boeing Company

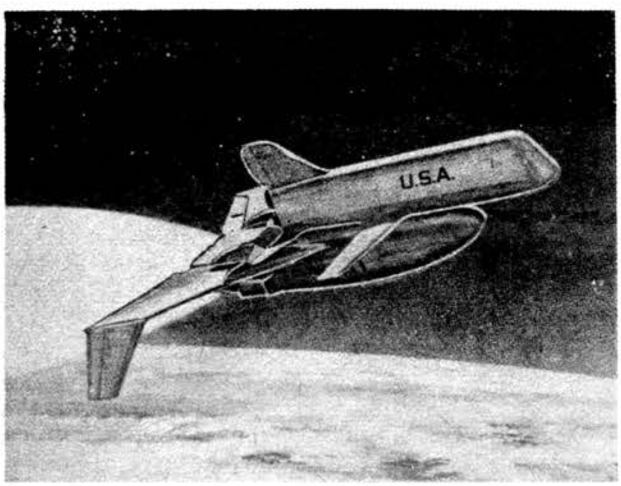


In this painting by Boeing artist Jack Olson a complex space station is assembled in Earth orbit with the help of space shuttles. Astronauts are attaching to the station a multi-sensor instrument pod brought into orbit by one of the flyback vehicles. The central core of the station, which contains crew living quarters, is assumed to have been launched intact by a large expendable booster. Object of the station would be to carry out Earth resources experiments, make geological, agricultural and weather surveys, develop air traffic control techniques and improve methods of Earth communications via space links. The re-usable shuttle, capable of making numerous round trips into space, makes possible the construction, repair and maintenance of such large space platforms.

The Boeing Company

Boeing contender for Phase B study of NASA/USAF space shuttle, early 1970.

The Boeing Company



American Airlines, with an eye to regular space operations, were taking a close look at maintenance, ground handling, and turnaround techniques.

The Phase B plan was divided into three working periods, a configuration selection period of 3 months duration, a systems selection period of 3 months, and a 5 month period for preliminary design and costing analysis.

The study was charged with considering only the fully re-usable system comprising a manned booster launching a manned orbiter. The baseline that emerged for the Space Division contract had a gross lift-off weight (GLOW) of 3.3 million lb. The reference mission adopted assured the use of a 12-man space station with appropriate requirements for logistics and crew rotation. Incorporating the requirements of the DoD brought two-fold assault on the design problem. A low cross-range orbiter, capable of manoeuvring 200 miles either side of the ground track, and a high-cross-range orbiter, with 1,500 nautical miles lateral manoeuvrability, were examined, thereby enabling NASA to make a final selection at the end of the definition phase in mid-1971.

It was decided to accept a commonality on propulsion with the booster and the orbiter, using LOX/LH_2 engines in both vehicles. The expansion skirt for each vehicle would be tailored according to barometric requirements. Thrust was established at 400,000 lb.

Finally, the Shuttle would be required to fly at least 100 missions before refurbishment or replacement.

The problem of high cross-range designs were confounded by the necessity to effect a high angle of attack at entry interface. To satisfactorily achieve the 1,500 n.m. cross range the orbiter must exhibit a supersonic L/D of $\geqslant 1.8$. This exposes the underbelly of the entire mass to heating in excess of that experienced on any surface of the low cross-range design which, at entry interface, has a typical angle of attack of 60°, and an L/D of $\triangleq 0.5$ at maximum C_L. At this point in the lift co-efficient curve the rear portion of the orbiter would be exposed to maximum heat pulses, none of which would approach that of the high cross-range design.

Lifting bodies had long been viewed with interest as potential Shuttle concepts but had design weaknesses due to an adverse body shape, a complex fabrication of the double curvature profile, and a large base area yielding a low subsonic L/D.

Other alternatives looked at had a variable geometry feature but these were considered unattractive due to a high vehicle weight to planform area ratio, resulting in adverse base heating temperatures and increased complexity due to the mechanical linkages required for movement of the wings.

The two baseline designs that NR took to a definition phase were a low, swept, fixed wing configuration and a low swept delta planform, the latter achieving high cross-range manoeuvrability. The selected booster was common to both orbiter designs and featured a low high-aspect ratio wing with a V-configuration tailplane.

2. Phase B Design Proposal

Let us first examine the low cross-range orbiter. The common booster to both this and the high cross-range orbiter will be discussed later. The design brings us to June 1970, the beginning of Phase B studies.

The straight wing orbiter, designed for low cross-range manoeuvrability, had a payload capability of 45,000 lb. to a 240 n.m. orbit at 55°, the design reference orbit. This value was computed assuming **an I_{sp} of 459 lb-sec/lb** from the

Hi-Pc engines for a gross weight of 759,417 lb. The selected nozzle expansion area of 120:1 for the orbiter carried an exaggerated sensitivity on payload degradation. A 1 second variation in I_{sp} would reduce payload weight by 11%.

The low cross-range orbiter featured a flat bottom planform with a high entry angle emphasis on minimised heating, possible due to the absence of a hypersonic trim requirement.

The basic configuration matured during the earlier Phase A effort from a conception drawn up at the Manned Spacecraft Center and delivered to NR for analysis. The wing structure used Haynes 188 on the mid-span centre section and undersurface trailing edges, Ti 6A1-4V on the upper trailing edge and reinforced pyrolised plastics on the leading edges. A large fillet was assumed to assist flow conformity across the wing leading edge and fuselage during hypersonic flight.

The basic load-carrying structure of the fuselage was to be titanium alloy with a protective thermal shield.

The nose section contained the flight deck, passenger deck, and avionics. The depth of fuselage, made necessary by the 15 ft. diameter cargo bay, provided a natural design location for placing the passenger deck directly beneath the flight deck, with seating for 10. From the flight deck an airlock gave access to the cargo bay for unpressurised situations.

The fuselage centre section contained the 15 x 60 ft. cargo bay and beneath this two floating aluminium LOX tanks. Circular in section, slightly tapered at the forward end, and uninsulated, they lay beneath the forward section of the hold.

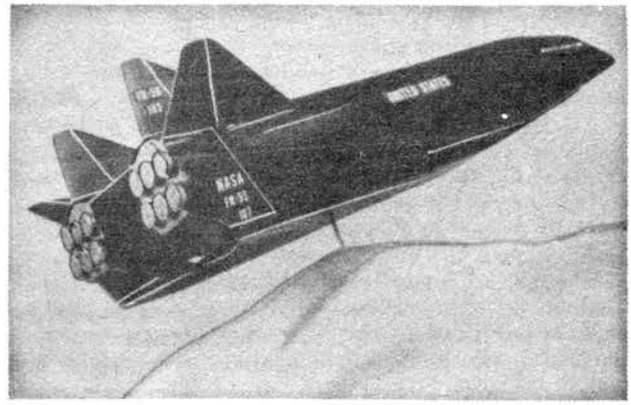
To the rear of these tanks were the two main wing spars in a carry-through structure that also provided a stress member for mounting the four JTF22B-2 turbofan engines, deployed from their stowed position for a powered flight to touch-down or ferry duties between sites in the event of an abort. Fuel, LH_2 was to be carried in tanks above the front and rear spars, beneath the rear section of the cargo bay.

The aft fuselage was dominated by the floating LH_2 tank, circular in section and internally insulated. This was to be fabricated from 2219-T81 aluminium providing fuel for the main propulsion system. Formers were provided for support structures to which were attached the independantly hinged horizontal stabilisers, vertical fin and thrust structure. Propellent for orbital manoeuvring engines was carried below the fin.

The main engine bay had provision for two main engines and two orbital manoeuvring engines. The main engines were mounted in a horizontal parallel configuration with nozzle clearances permitting a ± 7° pitch and yaw gimbal.

Attachments for booster mounting conformed to the structural frame of the vehicle and were located ahead of the retractable turbofans and on the bulkhead supporting the rear stabilsers.

The low cross-range orbiter was designed to perform a high angle of attack trim capability in subsonic supersonic and hypersonic regimes throughout the entire range of c.g. The entry profile began at the 400,000 ft. level with zero bank and a 60° angle of attack from a -1.55° entry gamma. For a maximum cross-range steering of 200 n.m. the bank angle was from 0° to 79° at the 300,000 ft. mark some 264 sec. after entry interface and a *g* of 0.5. Maximum *g* of 1.75 was reached nine minutes later with a 20° bank angle. Transistion trims the angle of attack to 10° with velocity down to 400 ft/sec. holding a constant 1g some 17 min. after E1. At this point the turbofans were deployed for an 11 min. flight

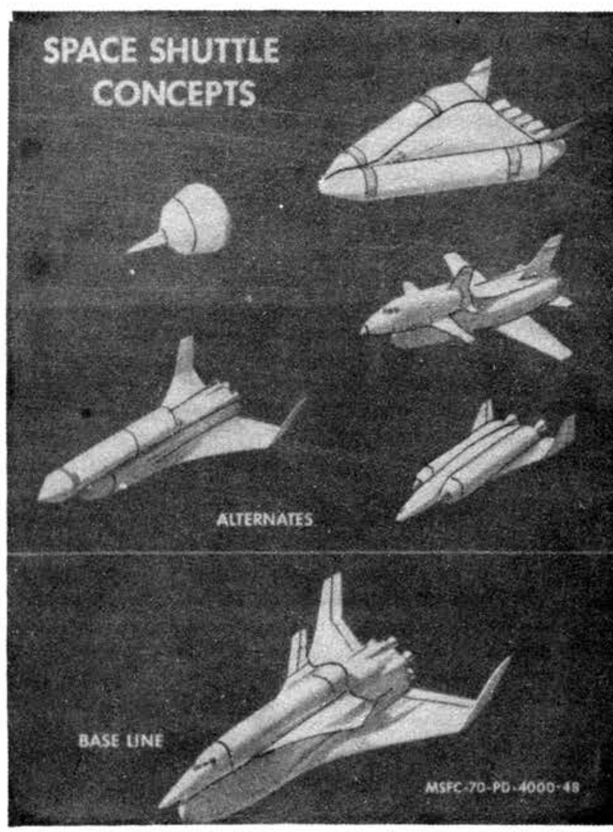


Skymaster concept of the space shuttle developed by Martin Marietta was also a contender for Phase B definition studies, subsequently awarded to North American Rockwell and McDonnell Douglas in June 1970.

Martin Marietta Corporation

Space Shuttle Concepts (Manned Space Flight Center, 1970): *Alternates.* Feasibility studies awarded to Chrysler, Grumman and Lockheed in July 1970 to study different approaches to the shuttle from Baseline. *Baseline.* The two-stage dual manned shuttle definition study awarded to North American Rockwell and McDonnell Douglas in June 1970 (to last one year).

National Aeronautics and Space Administration



to a 149 knotts touchdown at an angle of attack 12° from the horizontal and an approach path of 3.0°.

The external shape of the orbiter was governed by a requirement for stability and low thermal constraints. At entry the flat bottom provided lift with pitch stablised and trimmed by the negative body camber. The straight sides improved lateral and directional stability with flow separation facilitated by the acute edges around the fuselage.

During entry the configuration was self trimming to the 60° pitch angle with a C_L of nearly 1.6 and a L/D of 0.56. Transition to a 10° pitch at subsonic speeds lowered the C_L to 1.1 with a corresponding L/D of 8.0. Hypersonic and subsonic characteristics of this orbiter can be seen in the accompanying illustrations. The subsonic characteristics confirm the stability at high and low angles of attack with confidence in the aero-control mode for pitch translation.

During flight simulation trials the subsonic transition to a low angle of attack was made with little overshoot even though the manoeuvre necessitated moving from one stable equilibrium to another with nonlinear aerodynamic movements.

Maximum temperatures,experienced on the wing and tailplane leading edges, were induced by the interaction of fuselage shock waves. Reference to the temperature chart will show other high areas. Thermal protection for areas exposed to temperatures in excess of 1370°C was reinforced pyrolised plastics, with silicade coated Columbium C129Y for the 1090 - 1370°C range. Haynes 188 and Inconel 718 was to be available for thermal exposure to areas up to 98° and 730°C respectively.

The straight wing orbiter design was 183 ft. long with a wingspan of 125 ft.

The design of the high cross-range orbiter was related to placing a payload of 20,000 lb. into the reference orbit. The basic design inputs were compromised to achieve a large planform area for high entry pitch angles, good lift over drag characteristics, and a satisfactory subsonic performance.

The external shape was dictated by the quasi-delta wing form and inclined fin assemblies at the wing tips. The nose section provided sufficient volume for the LH_2 tank, a double-cell pressure vessel, situated beneath the crew and passenger compartments. The flight deck was located well aft of the nose and the passenger compartment filled the volume between the flight deck and cargo bay. An airlock allowed access to the payload area.

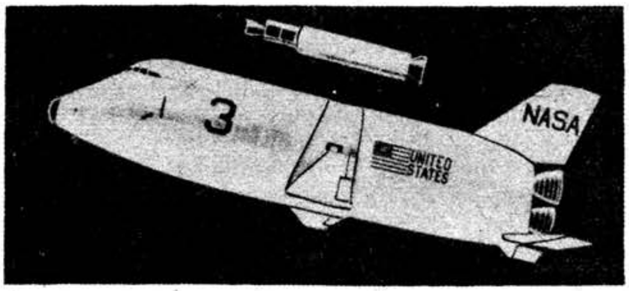
Main LOX tanks, situated on either side of the cargo bay, were unpressurised, and were allowed to 'float' to prevent induced fuselage loads translating to the tank structure. The wing carry-through structure lay beneath the LOX tanks and cargo bay, supporting the retractable turbofans. LH_2 tanks for the turbofans and propellent pods for the orbital manoeuvre engines alsolay within the wing structure in the fuselage. The engines used for ferry or landing duties were, like those of the low cross-range orbiter, deployed in two paired nacelles from beneath the underbelly of the fuselage.

Landing gear was similar to the other orbiter design also, employing dual wheeled steerable nose, dual wheeled main, undercarriage units.

The entry profile for the delta-wing orbiter incorporated a requirement for a 55° pitch entry followed by a translation to 35° less than 4½ min. later during the pull-up phase. An 81° bank ensured a post peak-heating translation across more than half of the cross-range distance required. Transition to a 20° angle of attack was to be made at supersonic speed some 26 min. after entry. Turbofans were started at 600 ft/sec.

Baseline Orbiter Configuration

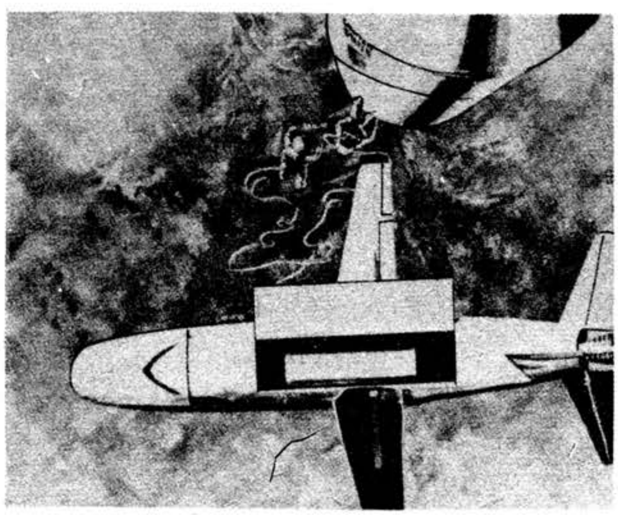
WEIGHT (lb)	*STRAIGHT WING*	*DELTA WING*
Structure and TPS	91,635	118,402
Landing & Docking System	10,288	9,620
Propulsion	40,292	42,294
Orientation, Control & Separation	8,858	5,239
Personnel	668	668
Main Propellent	508,286	506,570
Other Propellent	15,527	16,290
Other Subsystems	10,573	10,765
Lift-off Weight	723,946	723,946
Entry Weight	206,725	207,373
Landing Weight	204,324	205,277
Payload Weight	37,817	14,097

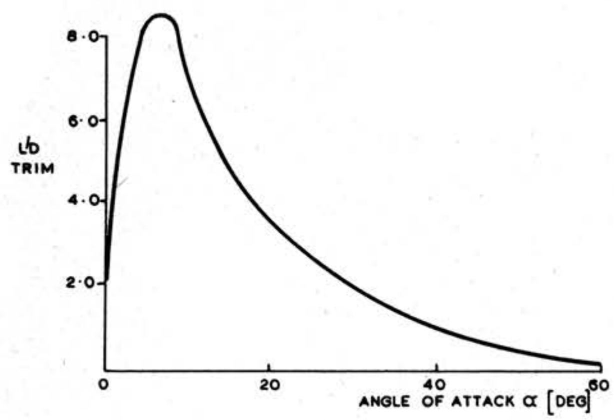


One configuration for the shuttle orbiter according to the McDonnell Douglas proposal at the start of Phase B studies in June 1970. The wings were assumed to fold against the sides of the fuselage for launching.

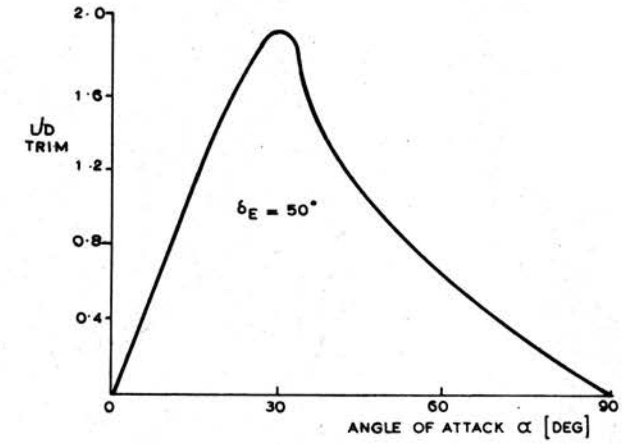
This view looks down on the open hatch of the cargo bay, two astronauts having moved to a space vehicle orbiting nearby. The wings of the orbiter are extended for re-entry and flight back to base.

McDonnell Douglas Astronautics Company

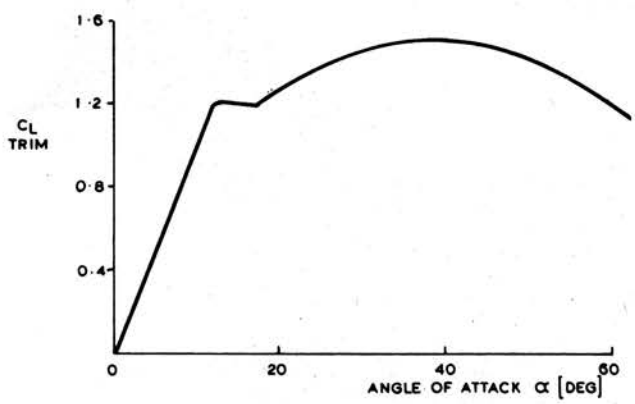




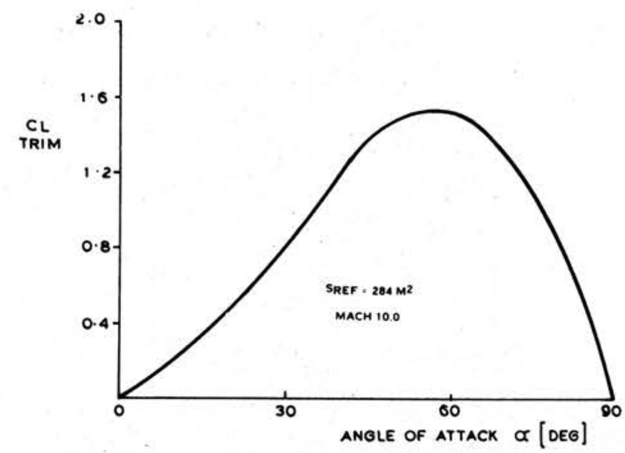
Subsonic flight characteristics: low cross-range orbiter.



Hypersonic characteristics: low cross-range orbiter.



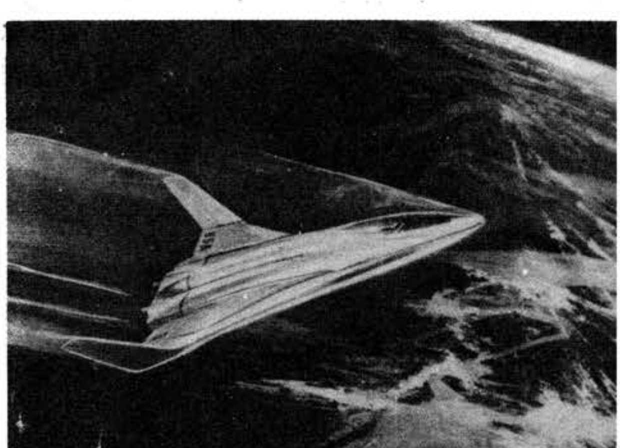
Subsonic flight characteristics: low cross-range orbiter.



Hypersonic characteristics: low cross-range orbiter.

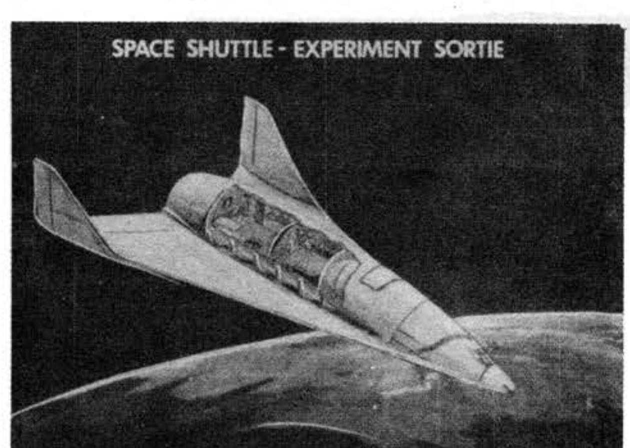
North American proposal for high cross-range orbiter at start of definition studies in June 1970.

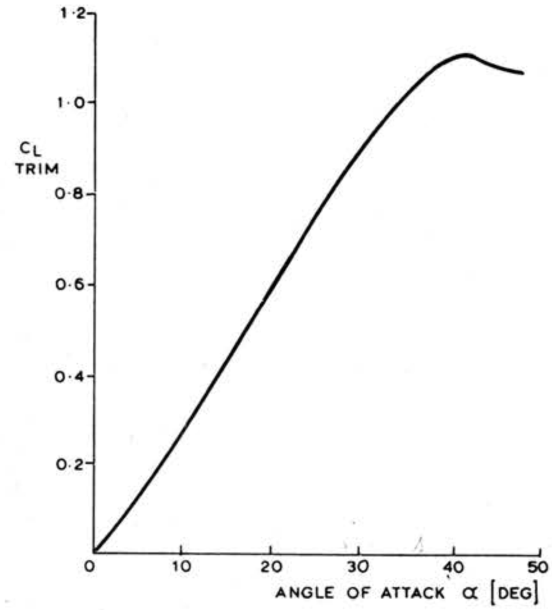
North American Rockwell



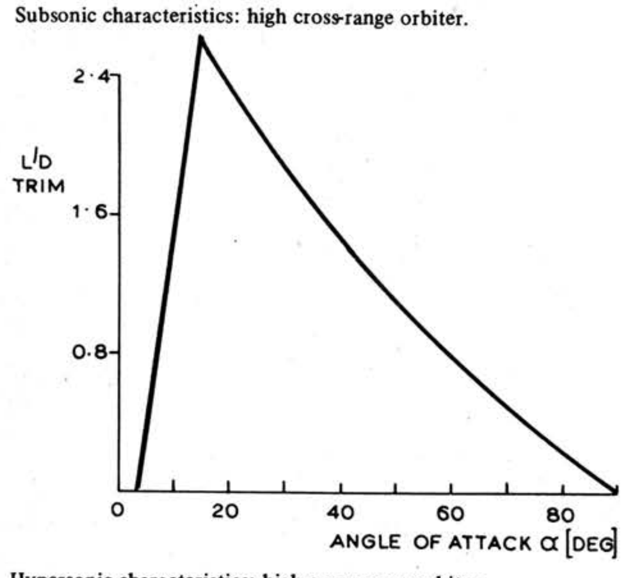
Baseline concept by Marshall Space Flight Center, 1970, with in-built experiment laboratory.

National Aeronautics and Space Administration





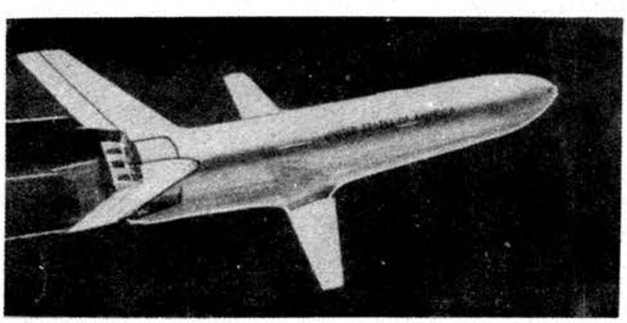
Subsonic characteristics: high cross-range orbiter.

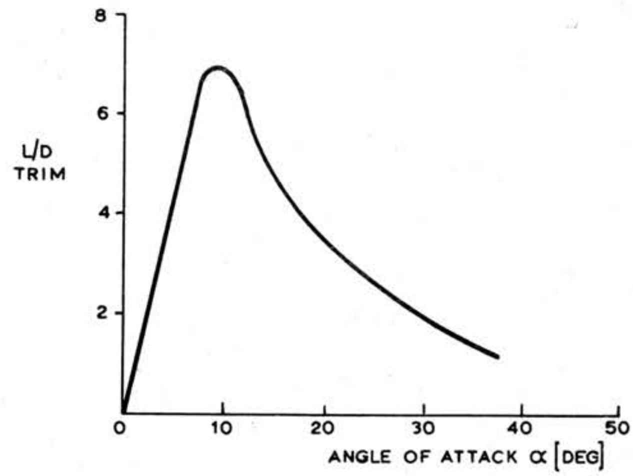


Hypersonic characteristics: high cross-range orbiter.

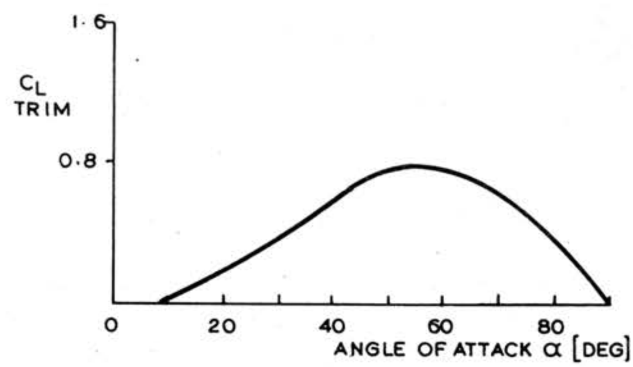
Booster concept by General Dynamics at the time of award of $8 million NASA study contract to shuttle team of GD and NAR, 12 May 1970.

General Dynamics





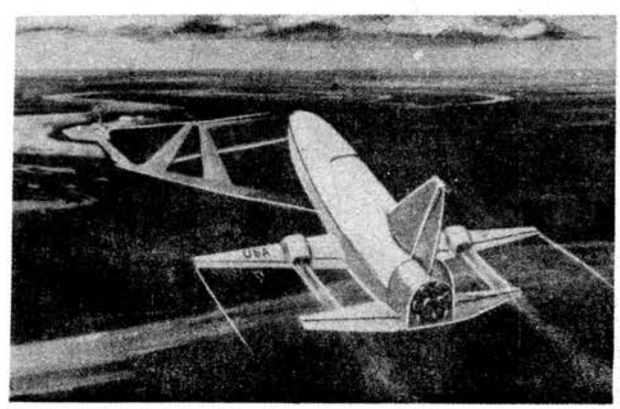
Subsonic characteristics: high cross-range orbiter.



Hypersonic characteristics: high cross-range orbiter.

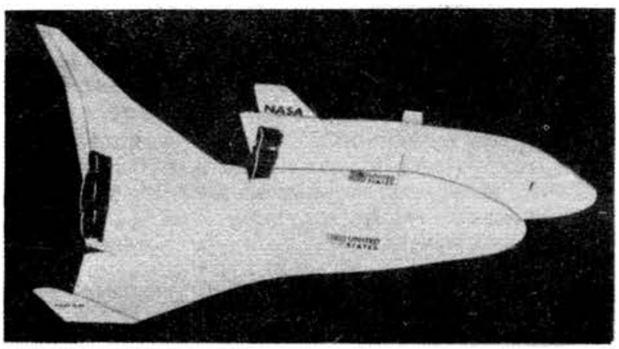
Early 1970 concept of fly-back booster by North American Rockwell's Space Division. Wing-mounted turbofans help vehicle manoeuvre back to base.

North American Rockwell



Baseline Booster Configuration

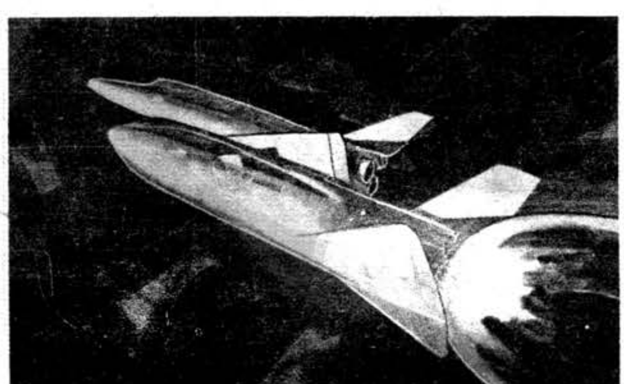
Wing Area	609.5 ft^2
Tail Area	718.9 ft^2
Planform	3,307 ft^2
Weights:	
Structure & TPS	252,334 lb
Landing & Docking System	18,480 lb
Propulsion System	128,995 lb
Orientation, Control & Separation	15,241 lb
Personnel	477 lb
Main Propellent	2,232,256 lb
Other Propellent	60,661 lb
Other Subsystems	9,334 lb
Lift-off Weight	2,738,222 lb
Entry Weight	478,781 lb
Landing Weight	463,990 lb
Payload Weight	759,495 lb



Model of McDonnell Douglas space shuttle concept, shown on page 206. The fly-back booster carries the orbiter from the launch pad to about 200,000 ft. altitude before separating and returning to Earth for re-use.

The final Phase B flyback concept studied by North American Rockwell (team leader) with Convair Aerospace Division of General Dynamics under an $8,000,000 contract to NASA, June 1971.

General Dynamics



with a constant 8° pitch to a landing some 47 min. after entry interface. Maximum *g* loads of 1.21 were experienced at transition, a value slightly less than that for the low cross-range orbiter.

The delta wing planform and aerodynamic fineness ratio gave high L/D at hypersonic speeds and an acceptable trim range over the entire flight regime. Attitude thrusters provided roll control modulation during entry. The aerodynamic characteristics of the vehicle gave a hypersonic L/D of 0.65 at 55° angle of attack, 1.4 when trimmed to 35°, and about 2.2 at 20° pitch. At 55° pitch the C_L trim was peaked at 0.7 with a tail off through 0.4 at 78°.

Subsonic characteristics provided an L/D of 1.5 at 35° pitch, rising to 4.0 at 20° angle of attack with a corresponding C_L, when trimmed, of 0.75. Peak L/D was 6.8 at 10°. The instability in low pitch regions during hypersonic flight was minimised by high forward fineness ratio and reduced body camber, resulting in low drag during the ascent.

Good directional stability was enhanced by the marriage of wing dihedral and vertical tail cant, as shown in the illustration. Rudders and elevons provided control with interlinkage to prevent aerodynamic coupling.

In this pre-Phase B design the landing speed was heavily influenced by vehicle weight. At 155,000 lb. vehicle weight touchdown speed was less than 180 ft/sce. rising to 210 ft/sec. at 220,000 lb. The low subsonic L/D was itself, of course, influenced by the basic design steerage toward high aerodynamic lift characteristics at hypersonic speeds.

The thermal history was biased by an increased pressure environment during bank modulation with peak loads up to 1370°C on the nose and wing leading edge. Thermal protection for these areas was silicide coated columbium on 2219-T81 aluminium alloy.

These two designs were each a compromise around the ideal value required for payload capabilities and operational performance. The payload capability varied by a factor 2:1 in favour of the straight wing design due to heavier thermal shielding of the delta configuration. Vehicle structure and thermal protection materials amounted to 96,134 lb. and 124,414 lb. for the straight wing and delta wing designs respectively. Of this the high cross-range orbiter required nearly twice as much material mass for thermal protection.

The high cross-range orbiter had a length of 192 ft. and a wingspan of 125 ft.

3. Fly-back Booster

The booster portion of the Shuttle was a manned, powered fly-back vehicle common to both orbiters and developed initially by NR with assistance from General Dynamics. GD took over booster design development during the Phase B study.

The design requirements were centred around the necessity to accelerate the orbiter to a satisfactory staging condition and then return for a dry, intact landing. The mission profile foresaw a vertical launch to staging at 42 miles in altitude and a velocity of 9,172 ft/sec. followed by a 4g re-entry and a cruise back to the landing site touching down on conventional runway at 155 knots. The orbiter, meanwhile, would have continued into orbit.

The booster itself was not required to perform any cross-range translation and therefore could be optimised around rapid and low cost refurbishment during the turnaround cycle. As will be seen from the chart the tail area exceeded that of the wings with a total platform area of more than 3,000 ft^2

providing most of the lift during the hypersonic glide to Earth. The baseline configuration featured a fixed straight wing and a Vee tail. The wing, chosen for its simplicity and low weight, gave an L/D of 6.7 at subsonic speeds from a hypersonic value of 0.5 quite satisfactory in view of the descent profile.

Structurally the design was configured to support a large LH_2 tank occupying more than half the internal volume and a LOX tank located forward. The extreme nose contained the two-crew flight deck and major subsystems, with four turbofans retracted into the fuselage directly behind this area. The LOX tank, forward of the LH_2 tank, assisted in maintaining the centre of gravity close to the centre of pressure. The propellent tanks, separate from the fuselage proper, were cylindrical load-bearing structures fabricated from 2219 aluminium.

Four major ring assemblies prevented interference with the tanks. The ring assembly located forward of the LOX tank gave structural support to the nose landing gear, thruster operation for attitude control, and deployment of the four air-breathing engines. The second ring, comprising the structure between the LOX and LH_2 tanks took loads associated with the forward attachment point for the orbiter. The main ring assembly, placed at the LH_2 mid-tank position supporting the wing tie-in point, took care of the main undercarriage loads and aft orbiter attachment stresses. A rear barrel assembly served as a thrust structure and Vee tail tie-in point, closing out the rear of the fuselage.

Propulsion systems for the baseline design included 12 main engines producing 4,800,000 lb. thrust at lift-off, 22 attitude control thrusters, and four 40,000-50,000 lb. thrust air-breathing engines for the cruise regime. The flight deck was designed to support a two-man flight crew with manual or fully automated flight control. The tricycle landing gear comprised a dual steerable nose wheel and a four-wheel cluster on either side of the fuselage centre-section in line with the trailing edge of the wing.

The large flat undersurface of the fuselage, with fixed straight wings and Vee tail, provided an inherent stability confirmed by the force co-efficients. The C_N value for the fuselage is largely independent of Mach number while that for the wing increases as the Mach number decreases. As the moment co-efficient must be essentially zero for ideal trim conditions the descending force co-efficient versus C_M confirms the inherent stability under transonic and subsonic flight conditions.

This booster design was 230 ft. 8 in. in length with a wing span of 141 ft. 3 in. and a height to the tip of the tail of 64 ft. A weight analysis is given in the table.

4. Summary

Thus far we have looked at the proposed baseline for Phase B studies re-usable Shuttle. Two orbiters, low cross-range and high cross-range, were married to a common booster for concurrent analysis. Little information on costing was forthcoming at this stage and it was this area alone that set the scene for a substantial re-appraisal of the design approach. In Part 2 we shall look at the changes that came to the Shuttle during the initial Phase B period.

A CHRONOLOGY OF THE SPACE SHUTTLE

By David Baker

1962-63

North American Aviation conduct a funded study for NASA on a reusable launch vehicle capable of lifting 200,000 lb. payload to Earth orbit.

Boeing conduct a NASA funded study on a reusable 200,000 lb. payload Earth orbit launch vehicle.

Lockheed study a recoverable 10 passenger orbital transporter.

1965

Apr — Lockheed and GD conclude a study of reusable space transporters.

Lockheed and GD conclude a joint study on reusable logistics vehicles.

1965-66

Dec Sep — Martin Marietta study reusable passenger space transporters.

1966-68

NASA conduct in-house studies on a fully reusable two-stage space transportation system.

1967

Lockheed conduct an in-house on the economics of space operations. Evaluation of Gemini-B vehicle displays the value of reusability.

1968

Feb 7 — Dr. George F. Mueller, then Associate Administrator for Manned Space Flight, tells Congress: 'The need for a launch vehicle to carry out logistics support of the station will be examined in context of the needs of other programmes and agencies which may also have requirements for a vehicle which drastically reduces the cost of transportation to orbit'.

Feb 28 — Dr. George E. Mueller, Associate Administrator, Manned Space Flight, NASA , testifies before the Senate that NASA is examining reusable logistics vehicles within, and in support of, its space station studies.

Aug 10 — Dr. George E. Mueller, Associate Administrator, Manned Space Flight, NASA, presents the concept 'of an economical launch vehicle for shuttling between Earth and orbiting space stations', at a meeting of the British Interplanetary Society in London. The proposed concept weighs 600,000 lb. at lift-off with a thrust of 750,000 lb. carrying 25,000 lb. to a 100 n.m. orbit.

1969

Jan 31 — NASA awards 4 contracts each valued at $500,000 to Lockheed (MSFC), General Dynamics (MSFC),

McDonnell Douglas (LRC, later to MSC), and North American Rockwell (MSC). Contractors to conduct parallel studies of an Integral Launch and Re-entry Vehicle (ILRV) to be concluded in Sep. 1969. Lockheed and North American Rockwell examined clustered or modular reusable fly-back stages and the latter expendable tank configurations. General Dynamics studied the expendable tank concept and modularised solid-propellent stages, with McDonnell Douglas concentrating on 'triamese' configurations and reusable fly-back stages.

Feb 13 President Nixon issues a memorandum to the Vice-President, NASA and DoD, for a definitive report on future space goals.

Feb Martin Marietta conducts a company funded study with MSFC of feasibility analysis of the Shuttle parallel with contracted Phase A studies on ILRV.

MSC begins in-house studies on the straight-wing, two-stage, fully reusable concept.

Apr 5 Space Shuttle Task Group formed in the OMSF at NASA Headquarters, Washington.

Apr 29 Lockheed, GD, MDC, and NR begin Phase A feasibility studies of ILRV.

Apr NASA/DoD begin a 3 month study to assess the degree of commonality for dual service with both agencies.

President Nixon establishes a joint NASA/DoD study group to evaluate the possibility of designing a joint logistics vehicle for both agencies.

Jun 20 NASA issues a revised study plan for Phase A ILRV work with supplementary payment of $150,000 to each of the 4 contractors. MDC receives an additional $225,000 for analysis of the fully reusable concept. Lockheed, GD and NR are also orientated towards this design approach.

Jun NASA/DoD space transportation study group issues a joint report endorsing the possibility of using one vehicle for both agencies.

Jul 1 Fiscal Year 1970 begins with Shuttle appropriations for the next 12 months of $12.5 million from Congress.

Sep 1 Space Task Group presents its report to President Nixon recommending an operational Shuttle by 1975-77 dependant on funding levels.

Oct 16 Boeing and Lockheed team together to study the Shuttle and bid for a Phase B definition contract.

Oct 29 IEEE EASCON Session on Earth Orbiting Manned Space Station endorses the desirability of a recoverable logistics vehicle of the two-stage fully reusable type.

Nov 1 Initial Phase A ILRV studies from MDC, NR, GD and Lockheed are completed. Martin Marietta also presents its internal studies to NASA.

1970

Feb 2-6 AIAA hold two consecutive meetings to discuss launch operations, thermal protection systems, entry simulations and the required booster capabilities.

Feb 17 A joint NASA/USAF Space Transportation Committee is established to preserve the interests of both agencies.

Feb 18 NASA issues RFP for Phase B difinition studies of a fully reusable Shuttle system.

Mar 7 President Nixon issues a policy statement on future space goals and assigns high priority to a reusable space transporter.

Mar 16 MDC announce selection of TRW to assist with the definition of avionics for the Shuttle in their bid for Phase B study contracts.

Mar 19 TRW, in association with Garrett Corporation's Air Research Division, deliver proposals to NASA for a definition study of the Shuttle's auxiliary propulsion system.

Mar 30 Phase B proposals submitted to NASA.

Mar NASA establishes a Space Shuttle Programme Office within the OMSF.

NR team with American Airlines in a bid for Phase B contracts.

May 12 NASA announces selection of NR and MDC for parallel 11 month Phase B definition studies on a fully reusable Shuttle. Each contract is valued at $10.8 million. Contractor selection for design and development phase is anticipated for late 1971.

Jun 4 NASA issue a funded contract to Mathemation Incorporated for an economic analysis of the Shuttle system.

Jun 11-12 MDC team brief MSFC personnel on the Shuttle.

Jun 15 NASA announce its intention to contract Grumman/Boeing, Lockheed and Chrysler for 11-month Phase A feasibility studies on alternative Shuttle designs. Grumman/Boeing receive $4 million to evaluate a stage-and-a-half Shuttle with expendable propellent tanks, a reusable orbiter with expendable booster, and a reusable booster using J-25 engines and solid propellent auxilliary boosters with a J-25 powered orbiter. Lockheed, with $1 million, to study expendable tank orbiter and Chrysler, with $750,000, a single-stage reusable orbiter. Grumman/Boeing managed by MSC, and Lockheed

& Chrysler managed by MSFC.

Jun 18 Shuttle presentation held for SAMSO/Aerospace at El Segundo, California.

Jun 19 TRW announce contract award from NASA for an auxiliary propulsion system definition study.

NR and MDC commence Phase B definition studies of a fully reusable Shuttle.

Jun 23 MDC brief MSC personnel on Shuttle.

Jun 24-26 MSC Shuttle Team visit MDC St. Louis for a technical review.

Jun At the onset of Phase B definition studies by MDC and NR a 183 ft. long 125 ft. wing span low cross-range, and a 192 ft. long, 125 ft. wing span, high cross-range, orbiter are used as baseline. The booster is 230 ft. long by 141 ft. wing span with a gross weight of 2,740,000 lb. Total booster/orbiter lift-off weight is 3.5 million lb. with 4.8 million lb. thrust at launch. Orbiter thrust at staging is 950,000 lb.

Jul 1 Fiscal Year 1971 begins with Shuttle appropriations for the next 12 months of $80 million from Congress.

Jul 7-8 NASA, NR and MDC teams meet ELDO officials in Bonn, West Germany, for talks in probable areas of European co-operation in the development phase.

Jul 15-17 Space Transportation System/Shuttle Technology Conference at Lewis Research Center, Cleveland, Ohio.

Jul MDC is awarded a study contract for thermal protection system costing to the Langley Research Center.

MDC is awarded study contracts by MSFC and MSC for high and low pressure auxiliary propulsion systems, respectively.

Pan American Airways hold a Shuttle flight operations and maintenance conference in New York.

Aug 3-4 Space Cargo and Packaging and Handling Conference held at Long Beach, California.

Oct 19 Lockheed propose development of a hypersonic transport carrying passengers on intercontinental routes on ballistic flights.

Nov 30 Grumman/Boeing brief NASA on mid-term Phase A studies along with Lockheed and Chrysler.

Nov Tentative NASA planning schedules the Shuttle for operational status by early 1975 concurrent with 12-man space station

Lockheed awarded study contract on cryogenic fluid supply systems for the Shuttle.

Dec 10 NASA announces MSC & MSFC modification of NR & MDC definition contracts to include $2 million study of structural testing, in addition to a $500,000 study on expendable stages and a $300,000 DoD study on Air Force requirements.

Dec 11 NASA holds mid-term review for Phase B definition studies from NR and MDC.

Dec 24 NASA announces MSC RFP for development of a computer programme for studying RCS engines.

1971

Jan 5 President Nixon announces his decision to proceed with development of the Shuttle. The statement was issued from the Western White House at San Clemente, California. Announcement also endorses the determination to proceed with either a solid or liquid propellent *unmanned* booster.

Jan 12 MDC announce that Aerospátiale have joined in Shuttle studies with analysis of propulsion, navigation and mission requirements.

Jan 19-20 NASA officials meet at Williamsburg, Virginia, to determine a single set of design characteristics. The delta-wing high cross-range design is selected with a 65,000 lb. payload capability to a due east 100 n.m. orbit.

Feb 9 MDC/ERNO presentation on Shuttle to the German Government in Bonn.

Feb 10 MDC/ERNO presentation on Shuttle to ELDO in Paris.

Feb Boeing tentatively propose an external H_2 propellent tank configuration for the orbiter.

Mar 1 NASA announces selection of Mississippi Test Facility for sea level testing of Shuttle main engines.

NASA issues RFP's to Aerojet Liquid Rocket Co., Pratt and Whitney and Rocketdyne for Shuttle main engine development. Proposals due by 1 Apr.

NASA announces plans to modify the former S-II stage test facilities at the Mississippi Test Facility for main engine testing starting in the second quarter of 1973.

Mar 2-4 Shuttle Aerothermodynamic, Structures and Materials Technology Review Conference held at Langley Research Center.

Mar 15 Phase B study data dump.

AIAA hold a Space Shuttle Conference in Collaboration with NASA at Phoenix, Arizona.

Mar 15-18 AIAA Space Shuttle Development Testing and Operations/NASA Technology Conference at Phoenix, Arizona.

Apr 1 NASA instructs Phase B contractors MDC and NR and Phase A contractors Grumman/Boeing, to study expendable external LH_2 tanks for the orbiter.

Apr 15 Hydraulic Research Division of Textron is selected by Rocketdyne to supply the Hydraulic Actuation System for the Shuttle.

Apr 19 MSC issue RFP for a human waste and storage system for the Shuttle orbiter which must be as earthlike as possible with long-duration capacity and of high reliability. Proposals to be submitted by 12 May.

Apr 20 NR Rocketdyne Division submitted its proposal for the Shuttle main engine.

Apr 22 MSC issue RFP for colour monitor for Shuttle with a 5,000 hr. lifetime. Proposals to be submitted by 10 May.

Apr NASA reviews 9 month results from Phase B studies by NR and MDC.

May 3 MSC issues RFP for safety study on Earth-orbiting Shuttles and Space Stations, analysing methods of escape, rescue and survivability. Proposals for submittal by 24 May.

May 4 MSC issue RFP for lightweight landing gear for the Shuttle orbiter with a 4 ft. diameter tyre inflated to 300 psi. Proposals for submittal by 17 May.

May 11-13 Space Shuttle Technology Conference on Integrated Electronics held at MSC.

May 14 MSC issue RFP for Auxiliary Propulsion System study with cryogenic propellents. Proposals submittal by 21 May.

May 17 MSC issues RFP for Thermal Protection Systems. Sample tiles are to be delivered 12 x 12 x 2 in. thick. Proposals for submittal by 24 May.

Jun 1 Mathematica Incorporated present an interim report to NASA on an economic analysis of the Shuttle.

Jun 10 NASA announces management plan for Shuttle. Overall management of Space Shuttle Programme will be in H.Q. Office of the OMSF; MSC will manage the orbiter and integrate the total configuration, MSFC will be responsible for the booster portion and main engine, with KSC reponsible for launch and recovery facilities.

Jun 11 MSC issue RFP for a model of the orbiter's cryogenic supply systems. Proposals for submittal by 2 Jul.

Jun 14 AIAA 7th Propulsion Joint Specialist Conference at MSFC confirms readiness of the Shuttle main engine design.

Jun 16 NASA announces its interest in a phased approach to Shuttle development with a manned fly-back booster deferred and an interim booster of conventional configuration providing early orbital flights. Industrial contractors to study modified Titan III, and solid propellent boosters.

Jun 17 Boeing announces award of a NASA contract to study design and test advanced structural panels for the Shuttle.

Jun 24 MSFC contracts Rocketdyne to develop turbopump assemblies for cryogenic auxiliary propulsion systems.

Jun 28 MSC announces contract award to NR for a safety and recovery analysis relevant to the Shuttle.

Jun 30 Lockheed present their final report on a Payload Effects Analysis conducted for NASA indicating multi-billion dollar cost savings using the Shuttle.

Jun At the conclusion of initial 11 month Phase B definition studies on the fully reusable Shuttle only the high cross-range orbiter remains (*see 19-20 Jan. 1971*). The MDC orbiter was 174 ft. long with a wing span of 107 ft. launched by a booster 270 ft. long with a span of 166 ft. Gross lift-off weight was 4.6 million lb. with a thrust of 6.6 million lb. Orbiter thrust at staging was 1.3 million lb. The NR design was slightly larger with an orbiter length of 206 ft, a 107 ft. span and a booster 269 ft. long with a span of 144 ft. Lift-off weight was 5.0 million lb. with a booster weight of 4.2 million lb. Thrust levels were identical to the MDC design. External LH_2 tank studies reduced the orbiter size for the MDC design to a length of 168 ft. a span of 117 ft. and a booster length of 218 ft. a span of 117 ft. and a gross lift-off weight of 4.1 million lb. Launch thrust was 3.8 million lb. with a third engine added to the orbiter increasing its thrust to 1.6 million lb.(*see Jun. 1970*).

Jul 1 NASA announces Phase B contract extensions to NR and MDC, with parallel uprated study contracts awarded to Grumman/Boeing and Lockheed. Contractors will study phased approach to Shuttle design and the use of existing liquid or solid propellent boosters for interim capability. Contracts worth $2.8 million each, except Lockheed's at $1.4 million. Contract period expires 31 Oct.

Fiscal Year 1972 begins with Shuttle appropriations

for the next 12 months of $100 million from Congress.

Jul 6 NASA selects MDC for design study extension on auxiliary propulsion system ($380,000 for 10 months).

Jul 14 NASA awards 7 month contracts to MDC ($325,000), General Electric ($319,200), and Lockheed ($322,500), for development and testing of a ceramic insulator for thermal protection.

NASA awards Phase A contract to NR for analysis of feasibility of a low cost, reusable chemical stage for the Shuttle booster ($250,000 for 10 months.

Aug 12 NASA awards contracts to Textron Inc., Bell Aerospace Div., ($484,400) and Rocketdyne ($460,445), for 14 month design and development for test of hardware for thermally controlling Auxiliary Propulsion System propellents.

Aug 13-15 NASA, DoD, and Shuttle contractors meet at Wood Hole, Massachusetts, for discussion with the Space Shuttle Panel of the President's Science Advisory Committee on economics and configurations.

Aug 26 MSC issues RFP for a proposed Atmospheric Science Facility.

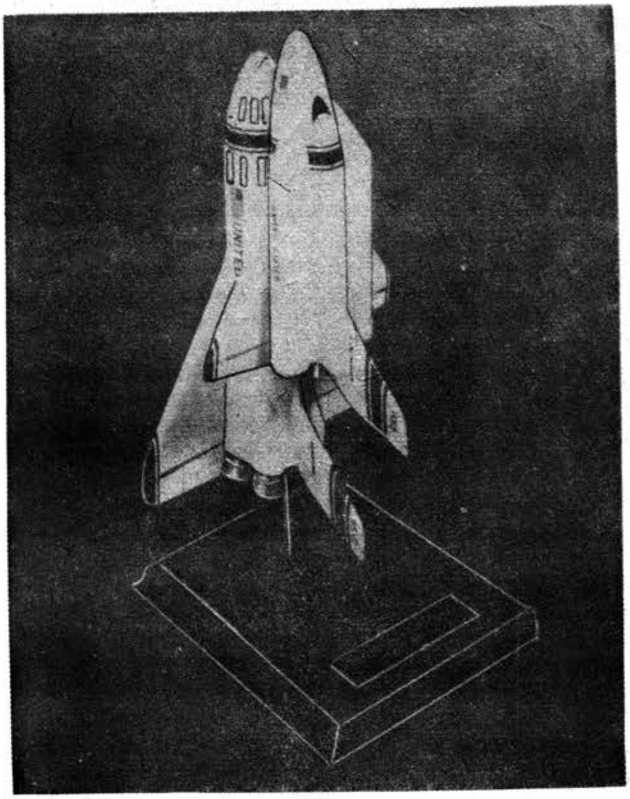
Aug NASA plans to issue RFP's for the orbiter in mid-December, 1971.

NASA decide to adopt an external Lox/LH_2 tank for the baseline orbiter with a Mk.1, Mk.2 approach in development. Mk.1 orbiters would use ablative thermal protection systems. Mk.1 first flight : 1978; Mk.2 first flight (with recoverable booster) : 1983.

Sep 1 NR, MDC, Grumman/Boeing and Lockheed, present their interim findings to NASA on mid-term results of Phase B extension.

Boeing propose adoption of the RS-IC, a reusable Saturn V first stage with added tail, wings and crew compartment, providing a lift-off weight of 6.5 million lb. with a length of more than 200 ft. and a wing span of 121 ft. A Grumman orbiter 147 ft. long and 90 ft. wing span would be attached in conventional piggy-back mode with external H_2 tanks. This approach would reduce development costs to $7,900 million. Boeing also propose an S-IC expendable booster with a forward 'shoe' supporting the external H_2 tank orbiter, and a solid propellent booster concept with Lox and LH_2 for the orbiter carried in a pod beneath the fuselage. Both booster and orbiter engines would fire at lift-off.

Sep NASA adopts Boeing proposal for RS-IC and informs all Phase B contractors to incorporate this planning in the study phase.



Compromise winged manned variant of first stage of Saturn V to reduce costs of developing an entirely new booster, September 1971. In this concept the orbiter carries expendable tanks for liquid hydrogen fuel.

The Boeing Company

NASA request Phase B contractors to study a ballistic recoverable using pressure-fed engines.

Oct 7 NASA announces a second Phase B extension to NR, MDC, Grumman/Boeing and Lockheed, to run until 28 Feb. 1972, with a 2 month option to 30 Apr. 1972. The baseline study would examine ballistic recoverable boosters, with either F-1 or pressure fed engines in a series burn, or twin pressure fed engines in a parallel burn configuration.

Oct NASA displays interest in liquid or solid propellent boosters for the Shuttle and also considers reducing cargo bay size and payload lift capability.

Nov 1 NASA awards 4 month studies to TRW ($400,000) and Aerojet General ($367,595) for feasibility studies of a pressure-fed engine for a water recoverable booster.

Nov 15 MSC issues RFP for development and test of polymer seals for liquid propulsion systems.

Nov 22 MSC issues RFP for EVA/IVA studies in orbiter design.

Dec 7 MSC awards 5 month contracts to NR ($99,000) and Grumman ($92,000) for preliminary design of a test bed for thermal materials with orbiter application.

Dec 17 MSC issues RFP for a design study leading to the development of Shuttle mission simulators.

[To be continued.

Introduction

For many people, a space suit epitomizes the whole buisiness of space exploration – toy manufacturers market pint-size space suits and helmets, cartoons show space pilots in the most unlikely places garbed in space suits, and space suits have even had an impact on women's fashions and on airline stewardess uniforms. While the space suit is a popular symbol for man's ventures into space, little is known, except by those directly involved, about what goes into the design and construction of these garments – which really are a sort of personal spacecraft that separates man from the hostile and deadly environment of space.

If an astronaut were to step onto the Moon unprotected, the gases in his body would expand and his body liquids would boil. Death would result quickly as oxygen flowed out of his lungs, blood, and body tissues. Furthermore, in sunlight, he would be scorched by temperatures as high as 250° F; and, if he stepped into a shadow or if night fell, the temperature would quickly drop to 100, 200, or even 250° below zero!

Fortunately, space suits that protect against these dire consequences can readily be designed. Neoprene-coated nylon will form a gastight layer which will hold oxygen as a pressure of 3.5 lb.per square in. producing sufficient force against an astronaut's body to maintain blood as a liquid, to retain gases in body tissue and fluids, and to allow normal breathing. Additional layers of a very thin, plastic-like film, coated with silvery aluminium and separated by layers of glass-fibre cloth, will provide superinsulation to protect against a wide range of heat and cold.

If protection against the vacuum and temperature extremes of space were the only function required of a space suit, the job of designing such a suit would be quite simple. Unfortunately for space-suit designers, astronauts must also be able to move about freely and must be able to perform intricate operations, often with the added handicap of weightlessness.

Walter Schirra's space suit is adjusted by suit technician Al Rochford in Hanger 'S' at Cape Canaveral (now Cape Kennedy) before the astronaut enters his Mercury capsule Sigma 7 on 3 October 1962. He completed 6 orbits of the Earth in a flight lasting 9 hr. 13 min.

National Aeronautics and Space Administration

Early Pressure Suits

Wiley Post, aviation pioneer of the early 1930's, was among the first to discover the problems of movement in a pressurised suit. Post proposed to make some cross-country speed runs in the 'Winnie Mae' aircraft and believed he would be most successful flying at altitudes above the weather, He contacted the B. F. Goodrich Company and proposed a man-shaped gas-bag, which could be pressurised from his aircraft supercharger. Early attempts at producing such a suit failed when Post discovered that his suit became rigid and immobile as soon as it was pressurised.

Because any inflated shape tends to form a sphere, Post's suit bulged tightly; and the arms, legs, and torso became so rigid that it was nearly impossible for him to bend. The problem, which has plagued pressure-suit designers ever since, was overcome by patterning Post's suit in a nearly fetal position, which allowed him to sit in the Winnie Mae with his arms extended stiffly toward the controls and his legs on the rudder bars.

Pressure suits improved in mobility gradually during the next 30 years. However, jet pilots, and even astronauts in the Mercury and Gemini programmes were tightly confined in the cockpits of their craft and had little need for leg and torso mobility.

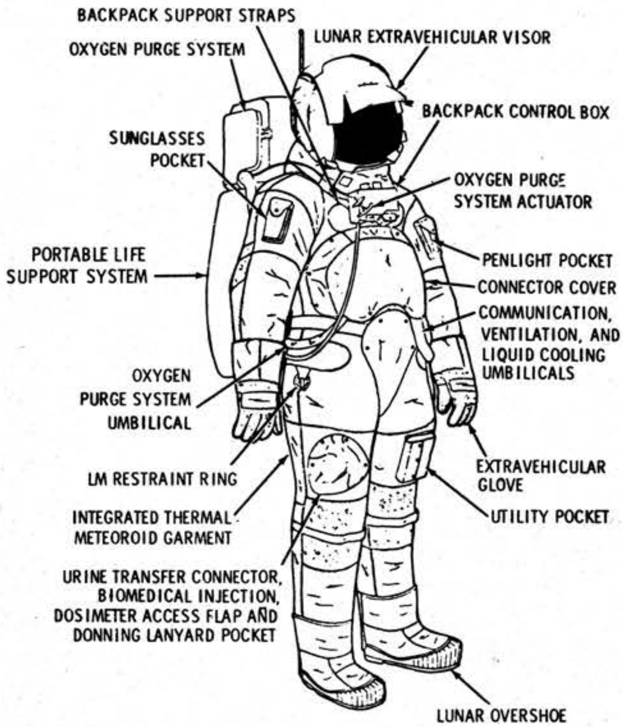
The Mercury Space Suit

The suit worn by Mercury astronauts was adapted from the US Navy Mk-IV pressure suit. It consisted of an inner layer of neoprene-coated fabric and a restraint layer of aluminized nylon fabric. Inelastic circumferential restraints were sewn around the elbows and knees of the suit to provide places where the cross-sectional diameter was less than that of the adjacent areas. These restraints were then tied together laterally so that the suit would bend when, say, the elbow was bent. Although this design provided a fair degree of mobility, the suit did not bend with the sharp hingelike motion of the human elbow but instead followed a gentle curve that limited the degree to which the arm could bend.

A good deal of energy was required to bend the suit joints, which folded in on themselves, reducing overall volume and increasing internal pressure. The Mercury suit was worn as a backup to the spacecraft cabin and would have been pressurised only if cabin pressure had been lost. [It never was]. The mobility shortcomings of the suit, when pressurised, were therefore less significant.

The Gemini Space Suit

Designers used a different approach for the space suit worn by Gemini astronauts. Instead of providing flexible joints, they used a combination bladder/linknet construction in an effort to make the whole suit flexible when pressurised. The bladder was made of lightweight, neoprene-coated nylon in the general shape of a man. The gastight bladder was covered with a layer of nylon or slippery Teflon strands woven into



Apollo Extravehicular Mobility Unit. 1 quart (0.9 litre) drinking water bags were attached to the inside neck rings of the EVA suits. The crewman could take a sip of water from the 6 x 8 in. bag through a 1/8th in. diameter tube within reach of his mouth. The bags were filled from the lunar module portable water dispenser.
National Aeronautics and Space Administration

a net and patterned to the shape of the body. Because the net had a surface area less than the area of the inflated gas bladder, the net became the load-bearing structure when the suit was pressurised. The same principle is used to shift the load in an automobile tire from the inner tube to the tire casing. This construction improved arm and shoulder mobility and made the suit more comfortable when it was worn unpressurised for long periods of time.

The Apollo Space Suit

For the Apollo programme, astronauts needed a suit which would allow them to climb through the small hatch of the lunar module, descend a ladder to the lunar surface, bend over to pick up lunar samples, and walk over the rugged lunar terrain. Designers recognised that the major problem in providing a more flexible space suit was to come up with a joint which could bend without compressing the gases in the suit. If, for example, one tries to bend a sausage-shaped balloon, he will find that it requires a surprising amount of force. As the balloon bends, it folds in on itself, reducing its inside volume and compressing the gas inside. If a joint which does not change in volume can be built, it can be bent quite easily.

Applying this principle, designers selected a constant-volume, bellows-like joint for the Apollo suit. When the joint is bent, is compresses on one side and expands on the other, maintaining a more or less constant internal volume. When properly constructed and balanced, a constant-volume joint will follow the astronaut's natural body movements freely and comfortably, even when the suit is fully pressurised.

In addition to affording astronauts much greater mobility, the Apollo suit had to protect them against micrometeoroids which, unimpeded by a lunar atmosphere, strike the surface of the Moon at speeds of five to six times the velocity of a rifle bullet. It had also to operate over a wide temperature range, in reduced gravity, and in intense ultraviolet radiation, which could permanently damage an astronaut's eyesight. It had also to be compatible with a portable life support system carried on the astronaut's back to provide breathing oxygen and cooling for the astronaut and to remove carbon dioxide and water from his breathing oxygen. The Apollo space suit was designed to satisfy these requirements and to permit astronauts to explore the lunar surface in spite of its hostile environment. The complete suit system required to do this job was called the extra-vehicular mobility unit.

A liquid cooling was the first layer of the space-suit assembly. The garment resembled a pair of 'long johns' with a network of spaghetti-like tubing sewn into the fabric. Cool water was circulated through the tubing to transfer metabolic heat from the astronaut's body. Progressing outward from the liquid-cooling garment, the Apollo suit had a comfort layer of lightweight, heat-resistant nylon called Nomex, a gastight bladder layer of neoprene-coated nylon which maintained the pressure of the suit, a nylon restraint layer which prevented the bladder from ballooning, a lightweight super-insulation consisting of alternating layers of very thin plastic-like Kapton and glass-fibre cloth, several layers of Mylar and spacer material, followed by protective outer layers of Teflon-coated glass-fibre Beta cloth and Teflon cloth.

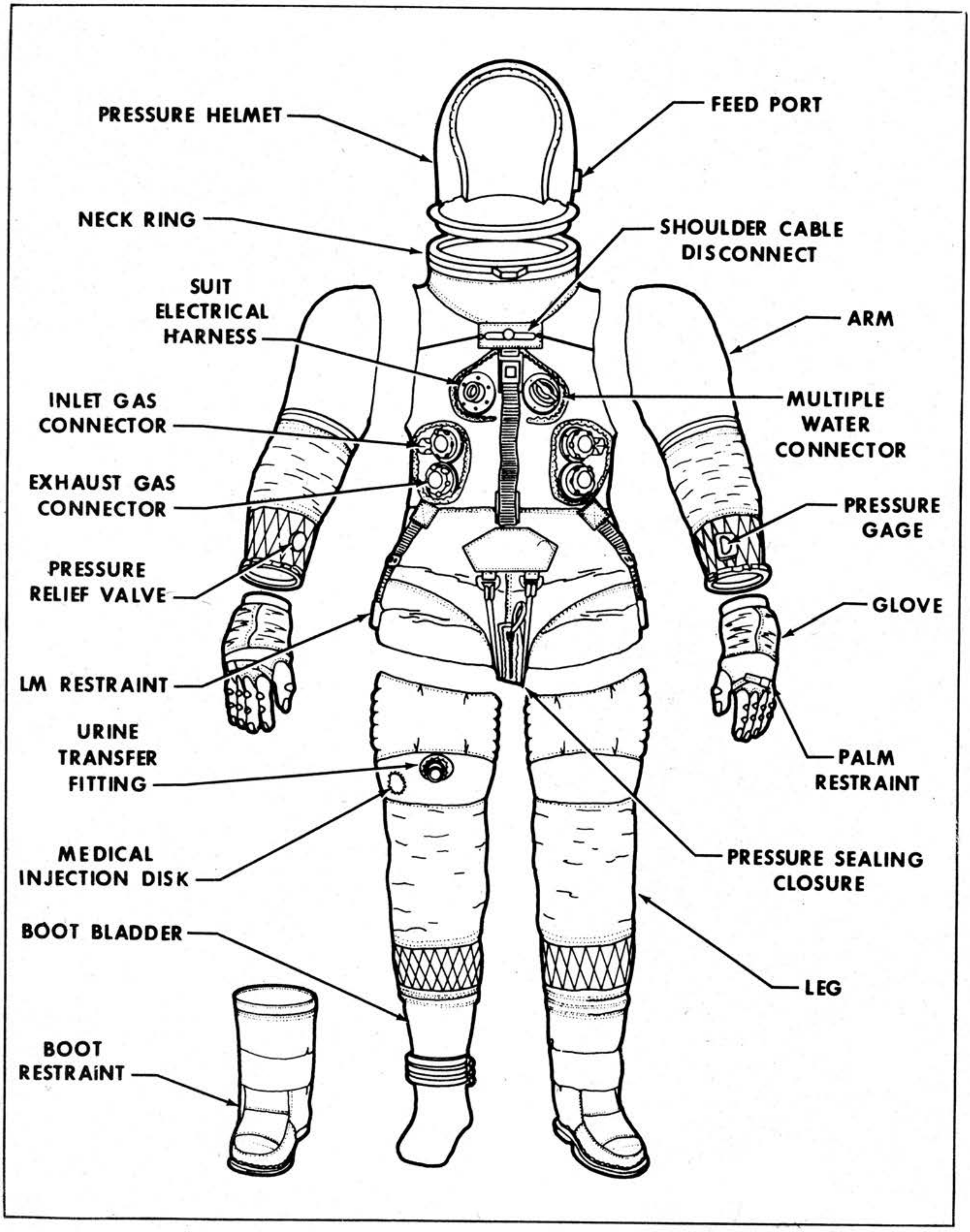
The space-suit helmet was formed from a high-strength polycarbonate plastic called Lexan, shaped like a bubble, and was attached to the suit by a pressure-sealing neckring. Unlike Mercury and Gemini helmets, which were closely fitted and moved with the astronaut's head, the Apollo helmet was fixed; and the astronaut's head was free to move as if it were in a fishbowl. On the lunar surface, an outer visor assembly was placed over the bubble helmet to shield harmful ultraviolet and other radiation which could damage an astronaut's eyes.

Gloves and Boots

The wardrobe of a well-dressed Moon-exploring astronaut would not, of course, be complete without gloves and boots, both of which presented some tricky problems for suit designers. If an astronaut is to function on the lunar surface, he must be able to manipulate his hands and fingers with enough dexterity to operate space-suit controls and lunar tools. He can be aided in his task by controls and tools that are designed to operate simply and that require minimum dexerity.

Developing a glove which would permit even rudimentary manual activity was no mean task. A glove, like any other part of a space suit, tends to form a sphere when pressurised. To hold the glove in shape, metal bars were placed along the natural palm creases of the hand. Extra insulation was required to protect both hot and cold objects which had to be handled on the lunar surface, and the glove needed an abrasion resistant outer layer to protect against possible damage and leaks. At the same time, the glove had to transmit some feeling or sense of tactility to an astronaut's fingertips if he were to grasp objects.

The lunar surface glove consisted of a bladder moulded from the individual astronaut's hand cast. Joints were pro-

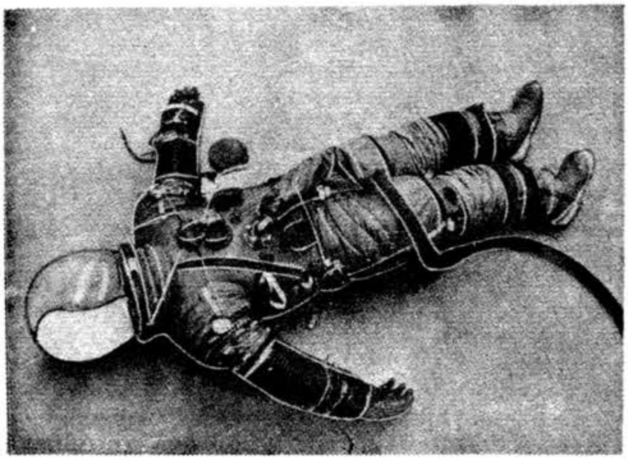


APOLLO SUIT MODEL A-7L

vided at the wrist and knuckles; and the bladder was covered with a multilayered shell. which gave the necessary thermal and abrasion protection. The glove thumb and fingertips were moulded of silicone rubber, which transmits some feeling to the astronaut's own fingertips and thumbs. The gloves were attached to the suit by a pressure-sealing ring much like that used on the helmet; and, like the helmet, they could be attached or removed quickly and simply.

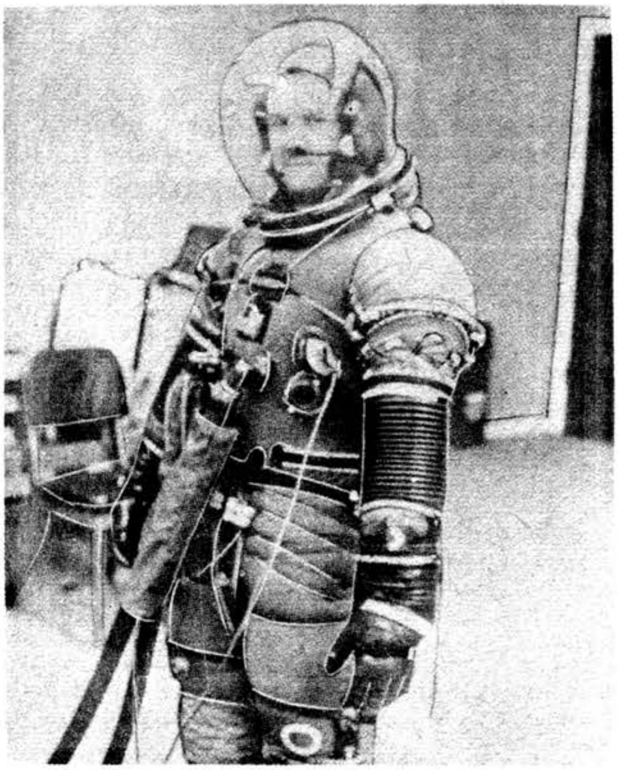
Gravity on the Moon is only one-sixth that on Earth, which means that an astronaut weighs only one-sixth as much as he does on Earth. Early in the development of the Apollo suit, it was found that an astronaut's reduced weight on the lunar surface would not flex the suit ankle sufficiently to permit him to stand flat on his feet. Instead, the pressure of the suit would extend the foot and force the astronaut to walk on his toes like a ballerina. The problem was solved by providing an ankle joint with metal restraints so the sole of the boot could remain on the lunar surface.

The lunar boot was actually an overshoe which the astronaut slipped on over the integral pressure boot of the space suit. Except for the sole, the outer layer of the lunar boot was fabricated from metal woven fabric; and the tongue area was made of Teflon-coated glass-fibre cloth. Ribs projected from the bottom of the silicone rubber sole to increase thermal insulation and to improve traction. The inner layers of the boot consisted of Teflon-coated glass-fibre cloth followed by 25 alternating layers of Kayton film and glass-fibre cloth which served as a highly efficient, lightweight insulation.



Conrad's complete PGA undergoing an extended pressure evaluation at ILC Industries laboratory in Dover, Delaware.

ILC Industries Incorporated



A suit technician tries out the pressure garment assembly (PGA) of Charles Conrad's Skylab spacesuit.

ILC Industries Incorporated

Support Equipment

The first time a US astronaut ventured from his spacecraft into the vacuum of space was during the Gemini 4 mission in 1965. Astronaut Ed. White received oxygen from the spacecraft through a 25 ft. umbilical. Suit pressure was established and controlled by a regulator in a small, chest-mounted pack.

For Apollo lunar exploration, these services were provided by a portable life support system (PLSS). The PLSS, which was carried knapsack fashion on the back of a suited astronaut, contained all required life support equipment for astronaut operations on the lunar surface.

The PLSS supplied oxygen at a pressure of 3.5 to 4.0 lb. per sq. in. to the pressure suit and also provided cooling water to the liquid-cooling garment. The astronaut's exhaled breath passed through lithium hydroxide in the PLSS to remove carbon dioxide. Charcoal and Orlon filters removed odours and foreign particles from the breathing oxygen. Heat was removed from cooling loops by evaporating water from an expendable feedwater supply.

Later models of the PLSS contained sufficient oxygen, lithium hydroxide, and feedwater to enable an astronaut to spend 7 or 8 hr. on the lunar surface before he need return to the lunar module and recharge the unit. In addition to the primary oxygen supply in the PLSS, each astronaut had an emergency oxygen supply known as the oxygen purge system. which provided additional 1½ hr. of breathing oxygen.

The PLSS was also equipped with its own communictions system so that astronauts could talk with each other on the lunar surface, with the Mission Control Center, and with their fellow astronaut in the orbiting command module. The communications system also transmitted medical data on the astronauts and status information on the PLSS which were relayed back to Earth.

The Apollo lunar surface space suit, complete with PLSS and backup oxygen supply, weighed about 180 lb. (30 lb. in the reduced gravity on the lunar surface). Each suit was custom sized and fitted to the astronaut who wore it.

SPACE REPORT

A regular monthly review of Space Events and Technical Trends

SOVIET ROVER ON MARS?

Academician Anatoly Blagonravov, in an interview with the newspaper *Pravda,* has forecast that a Soviet automatic roving vehicle may be landed on Mars. He describes the 8-wheeled Lunokhod 2 now at work on the Moon's Sea of Serenity as a forerunner of more advanced vehicles which would investigate in great detail many areas of the Martian surface.

Not only would they be able to map these areas, he said, but they would be able to lay out automatic science stations along their route.

Blagonravov said: 'There is no doubt that in the near future the first Mars rovers will be relaying information from the surface of that planet. Their prototypes are being tested on the Moon, which has become a kind of proving ground for space machinery'.

The launch window for Mars is open in July-August this year when the Soviets are expected to launch Mars 4, 5 and 6. Three French experiments will be carried on Mars 4 and 5. Optimum launch period (entailing lowest launch velocities) is 29-31 July. This suggests that a first attempt will be made about 21-23 July and a third about 6-8 August. Arrival times would then fall about 10-20 February 1974. (An article on this subject by Heikka Oja of the Astronautical Observatory, University of Helsinki, will appear next month).

However, there is no indication that these attempts will be anything other than orbiters capable of releasing landers during the approach – on the lines of Mars 2 and 3. The Mars rover could possibly be a candidate for the 1975 window using an up-rated launch vehicle, possibly the long-awaited type G.

SPACELAB

The European Space Research Organisation has authorised a 'Special Project' to develop a sortie laboratory to fly with NASA's reusable Space Shuttle in the 1980's. The project, to be called Spacelab, is conceived as having two elements, a pressurised manned laboratory module and an external unpressurised instrument pallet, suitable for conducting research and applications activities on Shuttle sortie missions lasting 7 to 30 days.

Spacelab's module and pallet will be carried into orbit in the payload bay of the Shuttle orbiter and will remain attached to the Shuttle throughout the mission, at the end of which the orbiter will make a runway landing at the launch site and the laboratory will be removed and prepared for its next mission.

The sortie lab will have sufficient flexibility to accommodate both a range of mixed experiments or equipment devoted to a single scientific or applications discipline. The laboratory module will house experimental apparatus, data processing equipment, electrical power equipment, an environment control system, and crew control stations. The staff of up to 6 scientists and engineers will eat and sleep in the Shuttle orbiter, but will carry out their experimental activities in the laboratory module working in a normal shirtsleeve environment. Pallet experiments will normally be remotely controlled from the laboratory. The pallet will be the mounting platform for large instruments such as telescopes and antennae that need wide viewing angles and direct exposure to space.

Countries that initially agreed to participate in the Special Project for development of the sortie laboratory were Germany, Italy, Belgium, and Spain. More countries were expected to join later.

Spacelab, estimated to cost between $250-300 million, will be funded by the participating nations of Europe. ESRO has already instituted studies of the preliminary design which are expected to be completed in December.

Assuming that cost studies confirm the general validity of estimates, it is intended that the ESRO Special Project will be continued through the stage of final design and development of the sortie laboratory, a flight unit being delivered to NASA in 1979.

MISSILE GUIDANCE FOR THE BLIND

Special eyeglasses which allow a blind person to find his way around by invisible infra-red light have been developed in America. Made by the Electro-Optics Division of the Sensory Aids Research Company of Albuquerque, New Mexico, the spectacles work on principles evolved for the navigation of guided missiles.

They look like ordinary glasses except that the side of the frames leading to the ear piece resembles a thin flashlight. Inside are two highly miniaturised units, a transmitter and a receiver for infra-red light.

As the blind person walks towards an obstruction in his path, pulses of infra-red emitted by the spectacles are reflected back to the receiver in the eyeglass frame, which emits a tone warning the person of obstructions. The company found that plaster walls which reflect infra-red light well can be detected at a distance of 10 to 13 ft. Objects which reflect poorly, such as certain fabrics, can almost always be detected at a range of five feet.

NASA EUROPEAN REPRESENTATIVE

Walter P. Murphy has been appointed NASA European Representative in Paris. In this position, which was established in 1964, Murphy will serve in a liason capacity between NASA and European space agencies on matters of mutual interest including the recently announced European Space Research Organisation's decision to develop a Spacelab to fly with NASA's reusable Space Shuttle in the 1980's. He will report to the Assistant Administrator for International Affairs.

Murphy graduated from the US Naval Academy in 1941 and pursued a Naval career, including assignments in missile and test-range work, until 1966 when he retired with the rank of Captain. He became Director of the Executive Staff of NASA's John F. Kennedy Space Center in September 1966. Murphy has a BS in electrical engineering and received the degree of Aeronautical Engineer from California Institute of Technology in 1948.

REMOTE SENSING MAP

Remote-sensing techniques being developed by NASA for space and aircraft investigation of Earth resources have been used to map land uses in an 18-county test site surrounding Houston, Texas. The multi-coloured map, prepared in 3 different scales showing up to 20 land uses, is now available for purchase from the US Geological Survey.

The experimental mapping project was carried out by the Earth Observations Division of the Lyndon B. Johnson Space Center (formerly Manned Spacecraft Center) to demonstrate the effectiveness of remote sensing as a means of preparing fast, accurate land-use inventories for large areas.

The Houston Area Test Site is a 15,700 square-mile region stretching from the Gulf of Mexico 125 miles north to Lake Livingston, and from east of Galveston Bay to Matagorda Bay in the southwest. The area surveyed, nearly twice the size of New Jersey, is used by NASA to evaluate remote-sensing techniques.

A specially equipped B-57 aircraft collected the information used to prepare the maps in 2 days of overflights at 60,000 ft. Stereo coverage of the region was provided by about 400 photographs.

Some 136 photographs, each covering about 275 square miles, were selected from itensive analysis. An average of one week was required for an interpreter to classify the areas shown on each photograph when 20 land uses were defined. A simpler classification of nine land use categories could be of nine land use categories could be completed in about half the time.

The 1 : 125,000 scale and 1 : 250,000 scale versions of the multicoloured map identify the following types of land use: industrial, commercial, public and semi-public services, cultural-entertainment-recreational, transportation-communications-utilities, urban (inactive), residential (developed), residential (under development), cultivated land (irrigated), cultivated land (unirrigated), orchard, pasture, agriculture related, non-productive, extractive, forest stand, forest brushland, reforested, marshes, and water.

The classification follows closely the 'Level II categories' referenced in the US Geological Survey publication Circular 671, 'A Land-Use Classification System for Use with Remote Sensor Data', published in 1972. The 20-category Land-Use classification was generalised to 9 categories on the single sheet 1 : 500,000 scale version.

Prepared with the cooperation of the State of Texas, the Houston-Galveston Area Council of Governments, and the Houston Chamber of Commerce, the mapped area includes the following counties: Austin, Brazoria, Brazos, Burleson, Chambers, Colorado, Fort Bend, Galveston, Grimes, Harris, Liberty, Matagorda, Montgomery, San Jacinto, Walker, Waller, Washington, and Wharton.

The 18-county map is available in three scales only from the Distribution Section, US Geological Survey, Federal Center, Bldg. 41, Denver, Colorado 80225. Prices are as follows:

6 - 1/2 x 8', 1 : 125,000 (1" to approx. 2 mi.) – $25.00/ set of 21 sheets.
3 - 1/4 x 4', 1 ; 250,000 (1" to approx. 4 mi.) – $5.00/ set of 4 sheets.
21" x 24", 1 : 500,000 (1" to approx. 8 mi.) – $1.00/ sheet.

ASTRONOMY FROM ORBIT

The second Small Astronomy Satellite (SAS-2) has carried out the most comprehensive study of celestial gamma rays ever undertaken. Its single scientific experiment – a spark chamber gamma ray telescope, one of the most advanced

gamma ray detectors ever placed in orbit – is operating flawlessly, according to project officials at the Goddard Space Flight Center. Since 19 November last when the experiment was turned on, it has made observations of gamma rays in the region of the galactic center, the galactic plane, and various X-ray sources including the Crab Nebula. Ultimately, a sky map of gamma rays will be prepared.

Studies of the galactic plane are of special interest since they have a direct relationship to understanding the galaxy's dynamics. The expansive pressures of the hot cosmic ray gas, the magnetic fields, and the kinetic motion of matter in the galactic disc, are counterbalanced only by the gravitational attraction of galactic matter in a manner not fully understood. Studies of X-ray sources are important in order to determine if gamma rays are emitted by these unique objects.

Gamma rays are a form of electromagnetic radiation similar to the photon packet in visible light. However, they are vastly more powerful, having energies ranging upwards from 200,000 times the energy of visible light photons. Gamma rays cannot be detected on Earth's surface because they are absorbed in the atmosphere.

The 186 kg (410 lb.) SAS-2, otherwise known as Explorer 48, was launched on 16 November 1972 by a NASA four-stage Scout rocket. The launch was conducted by an Italian crew from the Italian-operated San Marco Equatorial Range in the Indian Ocean off the coast of the Republic of Kenya.

Explorer 48 is the second of 3 spacecraft in the Small Astronomy Satellite series managed by Goddard. The first, Explorer 42 – called Uhuru, Swahili for freedom – was launched from San Marco on 12 December 1970. It has vastly widened knowledge of X-ray sources and their location. The third SAS is scheduled for launching in 1975 from the San Marco Range.

TRIUMPH OF 'COPERNICUS'

Copernicus, the Orbiting Astronomical Observatory 3 (OAO-3), has achieved its scientific and technical objectives and the mission has been declared a success by Dr. John E. Naugle, NASA Associate Administrator for Space Science.

Launched on 21 Aug. 1972, from Kennedy Space Center the 4,900 lb. (2.200 kg) observatory has been shown to have a pointing accuracy three times more precise than anticipated.

In the first five months of operation the two on-board experiments, provided by Princeton University and University College, London, made almost 2,000 observations of 92 ultraviolet and X-ray sources in the sky.

The Princeton Experiment Package (PEP), a 32 in. (82 cm) diameter reflecting telescope – the largest ever placed in orbit – made 1,780 observations of 37 different sources. It observes ultraviolet sources not visible to ground observatories because they are absorbed by the Earth's atmosphere.

Preliminary scientific results from the PEP reported thus far include:

(1) Detection of large quantities (more than 10%) of molecular hydrogen in the denser interstellar dust clouds. Hydrogen also occurs in atomic form in these regions;

(2) Observation of surprisingly large amounts of deuterium – a heavy form of hydrogen – in interstellar dust clouds. Deuterium is a basic element for fusion in the formation of stars, and current theories suggest that much of it should already have been used up. These theories may have to be revised in view of the abundance of deuterium observed;

(3) Determination that lesser amounts of heavier elements exist in clouds than in the Sun; and

(4) Determination that some solid particles or dust grains in interstellar clouds are smaller than believed previously – some less than one-millionth of an inch in diameter;

Preliminary scientific results from the University College, London, X-ray experiment involve 191 observations of 55 unique objects, with viewing accuracies superior to those expected. The most strking finding was that the period of rotation of the Cygnus X-3 binary system is increasing at a rate perceptible after only one month of observations.

Additionally, the experiment, now fully calibrated, has begun observation of clusters of galaxies in *Perseus, Coma* and *Virgo* as well as the supernova remnants in *Puppis.*

Another series of observations, scheduled during the next few months, will be to locate more specifically the several hundred X-ray sources already known to astronomers.

The OAO programme is directed by the Office of Space Science, NASA Headquarters. Project management is under the direction of the Goddard Space Flight Center, Greenbelt, Maryland. Goddard is also responsible for operation of the OAO Control Center and tracking and data acquisition.

The Grumman Aerospace Corporation, Bethpage, New York, was prime contractor for the OAO spacecraft. The PEP was built by Sylvania Electronics Systems, Needham, Massachusetts, and the Perkin-Elmer Corporation, Norwalk, Conneticut. The University College, London, X-ray experiment was built by a group of firms in the United Kingdom, including Pye Telecommunications, Cambridge; Elliott Brothers, London; and Rank-Taylor-Hobson, Hertfordshire.

ESRO 4 DETECTS POLAR ARGON

The launch of ESRO 4 last November into polar orbit with a perigee of 240 km instead of 280 km as planned has produced exciting early results from the gas analyser experiment (S80) of the Bonn University Physics Institute. This experiment is the first of its kind to be flown in such a low polar orbit and results obtained so far indicate unique possibilities for determining the composition of air as well as densities and temperatures in the upper atmosphere at altitudes between 240 and 600 km.

The performance of all 5 scientific experiments on board ESRO 4 has exceeded expectations, and all the spacecraft systems are working perfectly.

Professor U. von Zahn of Bonn University says that the gas analyser experiment, favoured by the low orbit, observed two main phenomena not previously measured:

(1) the existence of a concentration of argon gas over the summer pole of the Earth at least ten times greater than over the winter pole;

(2) considerable heating of the upper atmosphere over and

close to the polar caps, caused partly by solar wind particle interaction with the upper atmosphere.

The known phenomenon of increased heating of the upper atmosphere over *the equator* due to solar radiation had led to the assumption that temperatures over the poles (not previously measured) were lower. Now early results from the ESRO 4 gas analyser experiment indicate that in fact temperatures in the upper atmosphere are higher over the poles than over the equator, due to the heating of solar particles.

ESRO TD-1A REAWAKENS

Europe's first astronomical satellite, the TD-1A has been successfully reactivated for a second operational phase (which may continue until the end of October) after 3½ months' hibernation during the satellite's partial eclipse in the northern hemisphere.

ESRO decided to reactivate TD-1A for a second scan of the sky in order to achieve the scientific aims of the mission despite the reduction of data acquisition caused by tape recorder-failures. The satellite's planned operational life was 6 to 7 months following launch on 12 March 1972.

The operations to transfer the satellite from a spinning hibernation mode to its normal three-axis-stabilised mode of operation were undertaken by ESRO's Space Operations Centre (ESOC) at Darmstadt, Germany, and its ground station at Redu (Belgium), with the assistance of NASA stations at Madagascar and Johannesburg and the Norwegian station at Trömso. The European Space Research and Technology Centre (ESTEC) at Noordwijk, Netherlands, provided support for the operations, which started on 13 February, and ended 3 days later with the checking of the last experiment to be switched on.

Two of the satellite's 7 experiments had been switched on for various measurements shortly before the end of the hibernation period and remained operational during the despinning and reactivation. Measurements indicated that these and 3 other experiments switched on were working perfectly and suffered no degradation during hibernation.

'TUNGUS METEORITE'

The object which smashed into a Siberian forest in Jun. 1908 destroying 60,000 trees and killing a herd of reindeer was not a meteorite, according to a Soviet expedition which has returned from the largely uninhabited Tunguska region where the body fell.

The area still bears the marks of the collision which blew down thousands of trees which lay with their tops pointing outwards and away from the impact centre over several miles. Despite the devastation neither a crater nor meteorite fragments were ever found.

The expedition scientists completely reject the idea that the so-called Tungus meteorite was a solid body. Nor do they give credence to a Russian theory that it was an unexploded atomic-powered spaceship from another civilisation.

They are convinced that the Earth collided with the nucleus of a comet comprising frozen gas and dust. Had it fallen a few hours later it may have struck Leningrad or some other populated part of Russia.

NASA SEEKS 'ORANGE MOON'

American space scientists are now reasonably confident that corrections made to the path of Pioneer 10 will cause the probe to pass behind Jupiter's orange moon Io. The spacecraft, which left Cape Kennedy in March last year, has now emerged from the outskirts of the asteroid belt beyond Mars apparently unscathed. It is expected to photograph Io as it sweeps past Jupiter on 3 December.

Astronomers believe that Io, which is about the size of Earth's Moon, may have a thin atmosphere of nitrogen and methane. Seen through the telescope it is distinctly orange and very bright.

Io appears particularly brilliant after it emerges from Jupiter's shadow. This could mean that a temporary deposit of ice when the moon is in Jupiter's shadow melts again when it is back in sunlight.

GTS STUDY CONTACTS

Two important contracts in the field of space communications have been awarded to GEC Electronic Tube Company. English Electric Valve Company are to study a high reliability travelling-wave tube for the space-borne repeater in the British Geostationary Technology Satellite (GTS). The M-O Valve Company are also to study for the European Space Research Organisation (ESRO) the suitability of crossed-field amplifiers for use in communications satellites.

Marconi Space and Defence Systems are the design authority for a satellite communications repeater which will be used to carry out experiments in space related to broadcast TV transmissions from a satellite to community or domestic receivers.

ORBITING COMPUTER

A computer orbiting as an experiment aboard the OAO-3 satellite has been working so well that it has been given operational work to do. Known as the On-Board Processor, or OBP, the computer is a general purpose machine developed by NASA's Goddard Space Flight Center and the Westinghouse Systems Development Division.

The Orbiting Astronomical Observatory, the fourth and final satellite of the series, is named Copernicus. It was launched from Cape Kennedy on 20 Aug. 1972, see *Spaceflight*, **15**, pp. 18-19 (1973).

The OBP has been programmed to monitor the spacecraft's controls, to manage some functions on other experiments, and perform limited data handling and data reduction. The OBP can be reprogrammed, if necessary, to increase its usefulness. For example, the OBP experiment will help show that a space computer can satisfactorily perform many of the data processing functions that are currently done by ground computers. Engineers have been divided on this issue, but on-board data processing reduces ground telemetry bandwidth and significantly reduces the masses of data that must otherwise be sorted and processed on the ground.

The on-board processor is a low power relative of the Westinghouse division's series of military computers. They are normally used in airborne fire control radar systems, air-

craft weapons delivery systems, missiles, aircraft electrical system controls, and communications control. In conjunction with the OBP computer, efforts were made to develop low cost software and which can benefit future unmanned space programmes.

If the OBP continues to prove itself in this experiment, a more advanced version may be given the job of controlling future spacecraft during flight as well as performing data handling and equipment control functions. Already an Advance On-Board Processor or AOP, is being developed by the Westinghouse division under a NASA contract. Its capability will be substantially greater than that of other existing computers. Basic characteristics of the OBP and AOP are given in the following table.

Computer Characteristics:
On-Board Processor (OBP) and Advanced On-Board Processor (AOP).

	OBP	AOP
Speed (Operations/second)	100,000	250,000
Power (watts)	19.7	6
Weight (lb)	19	4
Volume (ft.^{3})	0.301	.55
Support Software	Yes	Yes
Arithmetic Section		
Data Flow	Par	Par
Word Size	18	18
Number System	FxFp2'sC	Fx 2'sC
Execution Time (usec)		
Add	10	4
Multiply	72	32
Divide	140	58
Direct add capacity	64k	64k
Addressable registers	6	6
Control Hardware	Yes	Yes
Logic		
Type	LPDTL	LPTTL MSI
Clock rate	0.5 MHz	1.0 MHz
Memory Section		
Address		
Core	DRO	Plated Wire
Max. Capacity	64K x 18	64K x 18
Cycle	2.0 usec	2.0 usec
Content protection	Yes	Yes
Input Section		
Number of Channels	2	1
Type	Digital	Digital
Number of Addressable Channels	16	8
Number of Interrupts	16	16
Output Section		
Number of Channels	2	1
Type	Digital	Digital
Number of Addressable Channels	16	16
Direct Command Channels		
Input and Output		Yes

A companion feature with the title of 'Space Science and Technology Report' will shortly be introduced into the JBIS. It will be similar to 'Space Report' in some respects, but deal more with technical aspects.

LARGE SPACE TELESCOPE

Astronomers throughout the world have been invited by NASA to propose participation in the definition and preliminary design of scientific instruments to be carried on the Large Space Telescope (LST) planned for launch by the Space Shuttle in the early 1980's. The LST, if approved as a flight project, will be a 3 metre (120 in.), diffraction-limited telescope that will permit investigation of objects up to 100 times fainter than now possible. Operating in Earth orbit, it will be visited periodically by the manned Space Shuttle for repair, maintenance and updating.

Major instruments expected to be mounted on the telescope are a diffraction-limited camera and low-and-high-dispersion spectrographs. Other instruments might include photometers, polarimeters, astrometric instruments, infrared instruments, and very-high dispersion spectrographs.

Scientists whose proposals are selected will be organised into instrument definition teams and work under contract to NASA with the Marshall Space Flight Center, Huntsville, Alabama, which is responsible for overall management of the LST project, and the Goddard Space Flight Center, Greenbelt, Maryland, which is responsible for the scientific instruments, data management, and orbital operations.

Initial briefings for scientists interested in submitting proposals were held in mid-January in the US and Europe. Further information may be obtained from Dr. C. R. O'Dell, LST Project Scientist, at the Marshall Space Flight Center; or Dr. J. Ortner, European Space Research Organisation HQ, 114 Avenue de Neuilly-sur-seine, France.

SPUTNIK SUN PALACE

Russia is to build an important international astronomy centre in the mountains of the Crimea, near the Black Sea resort of Yalta. Shaped like Sputnik 1, Russia's first Earth satellite, the centre will specialise in research on the Sun.

A system of lasers will help focus on a spherical screen a three-dimensional image of the Sun which will enable 300 scientists silmultaneously to observe sunspots, solar flares and other dynamic processes.

The centre will also have a special demonstration hall for tourists who will be able to follow the flight of artificial satellites.

INDIAN SATELLITE

Russia has agreed to launch a 550 lb. scientific satellite for India in 1974. Most of the satellite will be built in India but some of the structural parts and internal equipment will be purchased from abroad.

A plan to develop an all-Indian satellite launcher for orbiting a small Indian-built satellite next year has been abandoned. However, according to Professor S. Dhawan, head of the Indian Space Research Organisation, India still plans to build its own launch vehicle but this will not be ready for at least five years.

Novosti reported that a Soviet delegation led by Academician Boris Petrov recently visited Bangalore to finalize arrangements for implementing the former project.

STARSHIP STUDY: PROGRESS REPORT

120 members attended the Space Study Meeting held in London on 10 Jan. 1973 to establish the degree of interest in participating in an exploratory design study of an interstellar mission.

Alan Bond introduced the proposal and its objectives and mentioned that, although many papers on specialised aspects of interstellar flight had already been published, an integrated study of a realistic mission was needed to establish just how practical a proposition such a flight would be. The simplest mission should be chosen, i.e. a stellar flyby, with all aspects carefully studied. For example, a payload of suitable experiments should be determined,a payload weight obtained, guidance and navigation problems studied. Propulsion schemes should be examined and the most practical selected for integration into an overall design study. In his opinion , a propulsion proposal was now beginning to appear which might be capable of achieving a flyby flight to Barnard's star, 6 light years away, in a period of 30-40 years from launch. A flight-time of this nature would be the maximum acceptable, for then some of the younger people involved in the mission would still be alive when the destination was reached, and so some sense of continuity could be maintained. A launch date was projected at the end of the century. The flight would involve boosting the payload up to about 15% of the speed of light and then allowing it to coast to the destination. The encounter would consist of about 70 hr. of undecelerated flyby, during which time all measurements carried out in the system would have to be made. Even this simplest of missions would not be an easy study, and some years would have to be spent on it.

The next speaker, Dr. Tony Martin, went on to describe some of the more plausible of the available propulsion proposals and systematicaly reduced them to a single surviving candidate.

Controlled nuclear processes might yield two types of engine, i.e. those restricted by exhaust velocity and those restricted by weight. For example, the controlled fusion engine and the nuclear electric systems all have a very high mass associated with the hardware required to implement the system and hence the achievable acceleration is very low. This results in having to spend centuries just accelerating to the desired velocity – which is clearly not satisfactory for the present study. High-thrust devices such as the thermodynamic nuclear engines of the NERVA type could achieve the acceleration, but the low exhaust velocity of about 10^4 m/s meant that the amount of propellent required would be enormous and was impractical. In regard to photon rockets, Dr. Martin pointed out that, to attain $1g_0$ acceleration, the rocket would have to generate power at the rate of 3×10^9 w/Kg of vehicle mass. Not only this, but having generated the energy it was necessary to reflect it away from the starship with mirrors having an absorbivity of less than 1 part in 10^6! Only an electron gas mirror might do that and even this raised many doubts. There were two final possibilities. First was the interstellar ramjet. Despite enormous prospects for the future of this system, the idea was not well enough advanced today to allow any realistic appraisal of what such a vehicle might look like, or its capabilities. The problems of how to scoop up the tenuous interstellar medium with a density of about 1 atom/cm^3 were very difficult to resolve. If a magnetic field was employed, it would tend to reflect back into space the very particles it was attempting to collect. Even if the field problems could be overcome, bursting loads imposed on the vehicle structure were beyond our current technology. So, reluctantly, Dr. Martin moved to the only propulsion system which currently looks as though it might be practical, and capable of an interstellar mission. That was the nuclear pulse rocket. This device works by exploding relatively small thermonuclear bombs behind the vehicle and propelling it forward by the impacts received from the expanding products of the explosion. Because bombs were small, it would be necessary to ignite them by means of a high-power laser or electron beam, produced by equipment carried on the vehicle. To make the system more effective, detonations would take place in a cusp shaped magnetic field. This would not only make the exhaust more directional, but also reduce the ablation of the vehicle protection system to a negligible level. Two nuclear reactions may be possible for the bomb, a deuterium/tritium or helium 3/deuterium reaction. The latter one had low neutron production.

A velocity of more than 10^4 Km/s could be achieved with this rocket, and so might be able to meet the mission requirements.

The next speaker,Mr. James Strong,discussed some of the problems of interstellar guidance and navigation. He thought that these were alleviated by the relatively 'low' speed of the proposed vehicle and pointed out that none of the relativity effects would be very important. Normal stellar navigation should be applicable and the required guidance accuracy should be obtainable. Some degree of propulsion would be required for mid-course manoeuvres and for adjusting the trajectory to obtain the most profitable flyby, depending on the position of planets on arrival. In theory, at least, all control could be left in the capable hands of an advanced autopilot. It was envisaged that, on nearing its destination – after a thirty year or so sleep – the probe would activate itself, deploy sensors and communications antennae and generally ready itself for the encounter. The general guidance system should not offer any major problems. A trial period of ship-systems could be carried out beforehand by placing the vehicle in solar orbit with human attendants until the time came for it to depart on its mission.

Finally Mr. Tony Lawton returned everyone to Earth by pointing out the limitations of semiconductor devices in a cosmic radiation environment. Even the radiation received by the electronic devices from the motion of the vehicle at 15% of the speed of light relative to the interstellar medium would prevent operation of today's components after considerably less than thirty years exposure. Although future developments looked promising, this was one aspect of the study which would require a detailed investigation. The problem of communicating with the vehicle at interstellar distances was also raised. At the expected data transmission rate and distance it would require several hundred megawatts of power to be transmitted, or a very large unfurlable antenna would have to be carried. In either case the problems to be overcome in order that a remote probe might send back its data were considerable. The interstellar ramjet was interesting from the point of view of the electronics, in that the intake could provide protection from the radiation caused by motion of the vehicle. If the ramjet should prove practical and flight times could be reduced to not much more than 6 years, the electronics would survive much better and it might be possible to overcome the relativistic navigation problems by the use of inertial guidance.

An interesting discussion then developed in which speakers explored possible routes to study. It was gratifying that the theme of the discussion was on the level of *'which way is best'* and not *'what on earth do we want to do that for?'*.

Mr. Leonard Carter the Society's secretary began with questions on how attitude control would be achieved on the pulse rocket, and also why Barnard's star had been used as the objective.

Mr. Bond explained that attitude control could be achieved by altering the alignment of shock absorbers which were necessary to absorb the momentum from the bomb detonations.

Mr. A.V.Cleaver suggested that, on a vehicle of this type, it would probably be easier simply to reorientate the whole vehicle using small auxilliary engines, and then continue to thrust in the new direction.

Dr. Martin explained that the choice of Barnard's star had been made on the belief that it had an interesting attendant planetary system.

Mr. Bond added that the ability to achieve a mission to that particular star also implied that easier missions, e.g. to the Alpha Centauri system, could also be carried out. Longer missions were more difficult, due to the flight time : with present knowledge it seemed that this was about as far as the pulse rocket would be practical for.

The point was made by another speaker that, by the time such a mission was attempted, much more would be known about other planetary systems from space based telescopes and the choice would then be less arbitrary.

Dr. R.C. Parkinson added a further candidate propulsion scheme for examination namely the laser-powered sail. Here, a very high powered laser in a fixed orbit provides the photons to be reflected by a lightweight sail. The sail accelerates along the beam until no further useful velocity gain can be achieved. Dr. Parkinson recognised there would be heat transfer and mechanical difficulties, but thought that the advantages of not having to carry the power generation equipment along should be incentive enough to make examination worthwhile.

Several speakers thought that the society should look rather further ahead than immediate technology and advocated study of the interstellar ramjet. Both Dr. Martin and Mr. Bond said that the pulse rocket was the only system which was well enough defined to do any useful study on, but agreed that some effort should go into reviewing ramjet prospects.

Mr. Lawton suggested that the vehicle should carry simple experiments to announce its presence to any intelligent life in the target system. A large luminous cloud was suggested as an example, and some easily detachable artifacts should be carried which would identify the probe with Earth.

Mr. Cleaver said that with regard to the nature of the study, one should not try to relate it too closely to the BIS spaceship study of the late 1930's. With that study, there was far less untrod technical ground. Rockets of the solid propellent type had existed for many years and it was largely a question of tying together a lot of reasonably known entities. With the current starship proposal much was new territory. The non-nuclear ignition of thermonuclear reactions, for example, had not yet been achieved. He went on to add that, although the study could be valuable and should be done, it should be expected that the technology of a century or so hence would be as foreign to ourselves as transistors would be to Newton, and he suspected that when interstellar flight finally came it probably would not be done with any means we are aware of today.

Mr. Carter replied that although Mr. Cleaver was correct with regard to the technical aspects of the study, the present study had a far more receptive technical community to approach for contributions to the work. He took the view that the concept of a lunar flight in the 30's represented a much greater hurdle to even the scientific mind than does the concept of extrapolating interplanetary flight to interstellar flight today.

A member of the group put forward the suggestion that the main pulse rocket could be used for signalling purposes at the great distance involved,but Mr. Lawton thought this would prove impracticable, owing to the required rate of *data* transmission.

Replying to a question on the economics of an interstellar mission, Dr. Parkinson said that, by the turn of the century, the world's population will have doubled and projects of the sort that we are considering might actually be essential for employment and economic reasons.

The proposed Starship study will involve examining all aspects of an interstellar flyby mission to see if it is realistic and to establish some of the important interactions that occur on such a mission, e.g. how does the engine type compromise the payload and *vice versa.* Obviously one of the fundamental questions to be answered is the one of payload size required.

As the study will need to cover many disciplines, support is required from interested members. Three basic levels of effort are required. Firstly, those who can afford to spend a fair amount of time involved in the co-ordination of the study and integration to separate areas of work into a complete study. Next, and this will be one of the most sort-after contributions, are those who can contribute short technical papers, in which suggestions on particular aspects are made and taken through to analytical completion. The origins of the topic may either be the individual himself or a suggestion from the co-ordinating committee. Finally but still important will be those people who are able to make suggestions of new routes to follow, but have not the time or possibly the necessary knowledge to follow them through.

It is hoped that many members will join in this venture, and even, where possible, solicit material from expert sources not directly connected with the society. Those interested are invited to write direct and give details of the type of support they can provide to:-

Mr. A. Bond,
38, Sudeley Walk, Putnoe,
Bedford.

SATELLITE DIGEST – 59

A monthly listing of all known artificial satellites and spacecraft, compiled by Geoffrey Falworth. Information is based on that supplied by the Space Department of the Royal Aircraft Establishment, Farnborough, NASA, Satellite News and BIS sources. For information on the derivation of orbital parameters, abbreviations, etc., see July 1972 issue, page 262.

Continued from May issue, page 195

Name, designation and catalogue number	Launch date, lifetime and descent date	Shape and weight (kg)	Size (m)	Perigee height (km)	Apogee height (km)	Orbital inclination (deg.)	Nodal period (min)	Launch centre, launch vehicle and payload/launch origin
Molniya 1X 1972-95A 6294	1972 Dec 2.20 5 years	Cylinder-cone + 6 panels + 2 antennae 1000?	3.4 long 1.6 dia	596 447	39756 39908	65.01 64.88	717.70 717.7	Plesetsk USSR/USSR (1)
Apollo 17 1972-96A 6300	1972 Dec 7.23 12.58 days (R) 1972 Dec 19.81	Cone-cylinder + antenna + 2 booms 30358.28	10.37 long 3.91 dia	169 200	178 572080 Selenocentric orbit	32.56 33.2	87.82 26320	ETR LC 39A Saturn 5 NASA/NASA (2)
Saturn AS-512 1972-96B 6301	1972 Dec 7.23 3.63 days 1972 Dec 10.86	Cylinder 13930.96	18.69 long 6.60 dia	169 200	178 572080 Lunar impact	32.56 33.2	87.82 26320	ETR LC 39A Saturn 5 NASA/NASA (3)
Apollo LM-12 ascent stage 1972-96C 6307	1972 Dec 7.23 4.65 days 1972 Dec 11.83 1972 Dec 14.96 0.33 day 1972 Dec 15.29	Irregular cylinder + 2 tanks + antenna 2145.07	2.52 long 3.13 dia 3.76 high	169 200	178 572080 Selenocentric orbit Lunar landing Selenocentric orbit Lunar impact	32.56 33.2	87.82 26320	ETR LC 39A Saturn 5 NASA/NASA (4)
Apollo LM-12 descent stage 1972-96D	1972 Dec 7.23 4.65 days 1972 Dec 11.83	Octagon + cone + 4 legs + cylinder 2791.91	1.57 long 3.13 dia	169 200	178 572080 Selenocentric orbit Lunar landing	32.56 33.2	87.82 26320	ETR LC 39A Saturn 5 NASA/NASA (5)
Apollo LRV 3 1972-96K	1972 Dec 7.23 4.65 days 1972 Dec 11.83	Irregular frame + 4 wheels + boom + antenna 209.11	3.10 long 2.29 dia 1.14 high	169 200	178 572080 Selenocentric orbit Lunar landing	32.56 33.2	87.82 26320	ETR LC 39A Saturn 5 NASA/NASA (6)
Nimbus 5 1972-97A 6305	1972 Dec 11.33 1600 years	Conical frame + cylinder + 2 panels 716.68	3.05 long 3.35 dia	1089	1102	99.95	107.25	WTR SLC 2-West Delta NASA/NASA (7)
Molniya 2D 1972-98A 6308	1972 Dec 12.29 5 years	Cylinder-cone + 6 panels + 2 antennae 1250?	4.2 long? 1.6 dia?	495 465 471	39300 39886 39881	65.26 65.31 65.4	706.48 717.67 717.7	Plesetsk USSR/USSR (8)
Cosmos 538 1972-99A 6311	1972 Dec 14.58 12.7 days (R) 1972 Dec 27.3	Sphere-cylinder 4000?	5 long? 2.44 dia	205 184	283 282	65.40 65.43	89.38 89.16	Plesetsk USSR/USSR (9)
1972-99D 6325	1972 Dec 14.58 20.99 days 1973 Jan 4.57	Sphere?	2 dia?	177	285	65.40	89.12	Plesetsk USSR/USSR (10)
GRS 2 1972-100A 6315	1972 Dec 16.48 9 months	Cylinder + boom 127.01	0.71 long 0.92 dia	223	867	96.94	95.57	WTR SLC 5 Scout D FRG/NASA (11)
1972-101A 6317	1972 Dec 20 25 years	Cylinder? 1000?	8 long? 1.52 dia?	390	33800	63.11	596.7	WTR SLC 4-West Titan 3B Agena D DoD/USAF
Cosmos 539 1972-102A 6319	1972 Dec 21.08 5000 years	Cylinder + paddles?	2 long? 1 dia?	1343	1383	74.02	112.98	Plesetsk USSR/USSR
1972-103A 6321	1972 Dec 21.74 33 days 1973 Jan 23	Cylinder 3000?	9.75 long 1.52 dia	139 132 140	378 398 391	110.45 110.44 110.4	89.68 89.81 89.80	WTR SLC 4-West Titan 3B Agena D DoD/USAF (12)

Name, designation and catalogue number	Launch date, lifetime and descent date	Shape and weight (kg)	Size (m)	Perigee height (km)	Apogee height (km)	Orbital inclination (deg.)	Nodal period (min)	Launch centre, launch vehicle and payload/launch origin
Cosmos 540 1972-104A 6323	1972 Dec 25.96 120 years	Cylinder + paddles?	2 long? 1 dia?	781	810	74.08	100.79	Plesetsk USSR/USSR
Cosmos 541 1972-105A 6326	1972 Dec 27.44 11.9 days (R) 1973 Jan 8.3	Sphere-cylinder 4000?	5 long? 2.44 dia	221	346	81.31	90.21	Plesetsk USSR/USSR
 1972-105F 6342	1972 Dec 27.44 19 days 1973 Jan 15	Sphere?	2 dia?	220	323	81.32	89.97	Plesetsk USSR/USSR (13)
Cosmos 542 1972-106A 6328	1972 Dec 28.46 20 years	Cylinder + 2 panels + antenna	5 long? 1.5 dia?	527	641	81.22	96.38	Plesetsk Vostok USSR/USSR

Supplementary Notes:

(1) 25th communications satellite in Orbita network. Orbital data at 1972 Dec 10.6 and 1973 Feb 1.0.

(2) Astronauts Eugene A. Cernan, commander, Ronald E. Evans, command module pilot and Harrison H. Schmitt, lunar module pilot, flew Apollo 114 on a 301 hr 51 min. long mission to perform a manned lunar landing and return to Earth. For a report on this mission see Baker, D., 'The Last Apollo', *Spaceflight*, **15**, 42, 1973. Apollo 17 was the 25th US manned orbital flight, 27th US manned space mission, 11th manned Apollo flight, 9th manned space flight to the Moon and 6th manned lunar landing mission. Orbital data at 1972 Dec 7.24, Dec 7.37 and Dec 10.83.

(3) 27th Saturn launch, 12th Saturn 5 orbital mission, 10th Saturn manned mission and 5th Saturn S-IVB stage to impact the Moon. 1972-96B attached to 1972-96A until 1972 Dec 7.39 and impacted Moon at approximate astronautical selenocentric latitude 4°12' South, longitude 12°18' West at 1972 Dec 10.86. Orbital data at 1972 Dec 7.24, Dec 7.37, and Dec 10.86.

(4) 10th lunar module orbital flight, 9th LM manned mission to the Moon and 6th LM lunar landing mission. 1972-96C attached to 1972-96B until 1972 Dec 7.43, attached to 1972-96A until Dec 11.73, landed on the Moon at Dec 11.83, launched from the Moon at Dec 14.96, re-docked with 1972-96A at Dec 15.05, jettisoned at Dec 15.21 and impacted Moon at Dec 15.29 at approximate astronautical selenocentric latitude 19°54' North, longitude 30°30' East. Orbital data at 1972 Dec 7.24, Dec 7.37, Dec 10.83, Dec 11.83, Dec 14.98 and Dec 15.29.

(5) Attached to 1972-96C until 1972 Dec 14.96. Orbital data at 1972 Dec 7.24, Dec 7.37, Dec 10.83 and Dec 11.83.

(6) Attached to 1972-96D until 1972 Dec 11.99. Orbital data at 1972 Dec 7.24, Dec 7.31, Dec 10.83 and Dec 11.83.

(7) Nimbus E main objectives are to develop advanced passive radiometric and spectrometric sensors for daily global atmospheric surveillance providing long-range weather forecasting data basis and to compare vertical sounding techniques prior to Global Atmospheric Research Program (GARP) initiation, develop and evaluate new active and passive atmospheric sounding sensors mapping Earth's surface characteristics from geocentric orbit and extend higher spatial-resolution imaging into previously-uninvestigated spectral regions, develop further advanced space technology and Earth-based support techniques for meteorological and Earth-observation spacecraft, participate in World Weather Watch (WWW) global observation programmes by expanding daily global meteorological observation capability, and provide additional regular operational global weather data. Nimbus 5's 156-watts operational power plus 75-watts experimental power requirements are maintained by 10500 negative-on-positive silicon solar cells mounted on two constantly solar-oriented, 2.43-metres long, 0.91-metre diameter solar panels deployed from the spacecraft's upper conical framework section after orbital insertion. Constant Earth-orientation and three-axis stabilisation to within ±1° is maintained by a modularised advanced attitude control system mounted on the upper spacecraft structure comprising electronics, mechanical drives, pneumatic systems, horizon scanners, gas jet thruster nozzles and solar panel-mounted Sun sensors permitting initial post-insertion Earth acquisition and stabilisation and also reacquisition of nominal Earth orientation from any unplanned spacecraft attitude. Science and engineering data are transmitted during the spacecraft's nominal one-year active lifetime on ground command at 1702.5 MHz at 4 watts and 2208.5 MHz at 4 watts and spacecraft tracking beacon and additional ground-commanded telemetry at 136.500 MHz at 0.5 watt to 22 stations in NASA's Space Tracking and Data Acquisition Network while prime data acqusition facilities at Rosman, Fairbanks, Goldstone, Madrid and Honeysuckle acquire operational spacecraft data for near real-time processing and distribution. Nimbus 5's 1.52-metres diameter sensory ring assembly mounted below the conical framework assembly holding upper attitude control and stabilisation equipment, holds weather experimentation, instrumentation, electronics and data transmission systems, S-band and real-time transmission antennae deployed from the structure's base, beacon and telemetry antennae and onboard electronics system's thermal control louvres, spring-mounted to activate above certain spacecraft-measured temperatures, located at the experiment sensor ring's perimeter, and onboard power conversion systems. Nimbus 5's improved-flexibility command system permits reception of 512 ground commands and a higher telemetry transmission rate. Meteorological experimentation constantly viewing Earth from Nimbus 5's lower sensor assembly includes a rectangular electronically-scanning microwave imaging radiometer deployed from the side of the spacecraft after orbital insertion mapping thermal radiation emitted by Earth's surface and atmosphere at 1.55 cm-wavelength to study cloud-type differentiation and precipitation intensity of frontal and convective action and measure storm severity, morphology of water-borne ice and soil, water and vegetation content; 30-kg instrumentation and electronics and Earth-oriented panel antenna receiver using 42 watts is located on the lower sensor platform's exterior and views Earth with a 29-km resolution from orbit. Surface composition mapping radiometer, comprising high-sensitivity, 0.66-km resolution, mercury cadmium telluride detector cooled to 115°K by exposure to space, measures Earth-emitted residual radiation between 0.8 to 1.1, 8.3 to 9.3 and 10.2 to 11.2 micrometers in determinations

of nature and type of rock and sand surface composition, 1-micrometer channel in which chlorophyl reflectivity is high, and Earth-reflected solar radiation to differentiate between arid regions and vegetation; 32-kg sensor and data handling system providing tape-recorded and real-time data readout using 15.7 watts on a 10-minutes per orbit duty cycle views Earth from below Nimbus 5's experimentation platform and measures radiation variations between Earth-based highly-acidic quartz-type rock formations and normal rock strata. Nimbus 5's infrared temperature profile radiometer, consisting of a seven-channel scanning vertical temperature profile-measuring instrument comprising six Cassegrain telescopes aligned to an Earth-viewing scanning mirror and focussed on to seven pyroelectric detectors, one telescope system using a dichroic mirror splitting incoming radiation to focus di fferent spectral-region radiation on to two detectors while incorporating spectral filters selecting various channels including 15-micron carbon dioxide, water vapour, and vertical temperature profile measures spectra to determine Earth's surface temperature, vertical atmospheric temperature profile and atmospheric water vapour emissions; 19-kg experimentation located beneath Nimbus 5's experiment platform uses 22 watts and has a 35-km ground resolution to provide, in addition, in-orbit testing of proposed infrared radiometer operational remote temperature sounder for future operational three-dimensional atmospheric structure forecasts. Nimbus 5's microwave spectrometer measures Earth's atmospheric 5-mm wavelength oxygen line vertical temperature profile and tropospheric water and 1.35-cm wavelength water vapour radiance at a resolution of 185 km with a five-channel radiometer, three 5-mm wavelength channels acquiring vertical atmospheric temperature profiles and two 1-cm wavelength channels measuring water and water vapour resonance over oceans and surface temperatures during Nimbus 5's transits over land areas; located inside the spacecraft's sensor platform, 32-kg multichannel microwave radiometer spectrometer uses 33.5 watts of power. Nimbus 5's 16-channel vertical temperature profile selective chopper radiometer, using interference filters, selected chopping, dichroic beam-splitter filters and four channels using carbon dioxide absorption cells, has four main channels, two comprising conventional filter radiometers measuring vertical atmospheric temperature profiles at 18-km resolution, third channel containing radiometers measuring refraction indices of atmospheric ice crystals at 49.5- and 133.3-microns wavelengths to measure cirrus cloud cover and water vapour- and window-correction channels used in vertical temperature profile inversion computations, and fourth channel measuring Earth's absolute radiation temperature and dayside cloud cover in three regions, one at the 2-micron water vapour-carbon dioxide wavelength and two at the 2.6-microns absorption band, while the 3.5-microns channel measures dayside cloud-reflected radiation without gaseous absorption; Science Research Council and NASA joint project instrumentation, mounted below Nimbus 5's experimentation platform weighs 18 kg and uses 16 watts to observe global atmospheric temperature structure at altitudes up to 50 km over extended periods, global water vapour distribution, and cirrus cloud ice particle densitites. Onboard temperature humidity infrared radiometer provides supporting data on Earth's cloud cover, surface temperatures, water vapour distribution, cloud-free area identification and cloud-top temperature at infrared 10.5- to 12.5-microns atmospheric spectral window and at infrared, strong water-vapour, 6.5- to 7.0-microns absorption band during dayside and nightside transits, atmospheric window channel producing both two- and three-dimensional atmospheric cloud cover charts, latter being created by vertical temperature profile measurements allowing measured cloud radiances to be associated with specific altitudes, while absorption band measurements of radiation from specific altitudes allows water vapour distribution and cirrus cloud effects on emitted radiation to be measured; viewing Earth from below Nimbus 5's experimentation platform, 9-kg, 10-km-resolution infrared scanning-image radiometer uses 8.0 watts. Nimbus 5's surface composition mapping radiometer ceased returning useful data after operating for about three weeks after launch; malfunction, probably caused by fractured internal instrumentation wiring, involved loss of electrical pulses in the instrument used to clear previously-transmitted data from the spacecraft's data storage unit, resulting in data overflow.

(8) 26th communications satellite in Orbita network. Orbital data at 1972 Dec 12.3, 1973 Jan 2.5 and Jan 31.0.

(9) Orbital data at 1972 Dec 15.6 and Dec 16.5.

(10) Capsule ejected from 1972-99A at about 1972 Dec 26.

(11) GRS B, third Federal Republic of Germany spacecraft and second launched by NASA under a co-operative agreement between Bundesministerium fur Bildung und Wissenschaft and NASA initiated in 1969 Jun, investigates Earth's upper atmosphere, physical and chemical composition of ambient atmosphere and ionosphere and measures solar radiation for correlation with simultaneously-acquired satellite data and ground-based solar studies, Main spacecraft cylindrical structure, containing welded modules holding onboard science instrumentation sealed to prevent sensor and instrumentation interference by internal pressure differences and gas emissions which are vented to space through upper spacecraft structure-mounted vent ports, holds negative-on-positive solar cells mounted on the spacecraft's upper solar-oriented structure recharging onboard nickel cadmium battery system supplying 4.7 watts during non-active orbits and 34.3 watts during instrumentation activation periods, while internal silver zinc battery system provides power during initial spacecraft operation. GRS 2's attitude control system comprises despin weights attached to cables deployed from spin-stabilised GRS 2's mid-section after orbital insertion to decrease inherent satellite spin caused by fourth stage rocket injection procedures, passive mechanical oscillation damping system and an active magnetic control system interacting with Earth's magnetic field to correct spacecraft attitude and rotation deviations. Coarse alignment solar sensor used during initial solar acqusition viewing from the spacecraft's cylindrical structure and fine solar sensor viewing from the solar cell array determining solar aspect and solar azimuth angles, two pencil-type infrared sensors scanning Earth's horizon, structure-mounted ion sensor determining maximum ion flux vector and three-axis magnetometer determining Earth's magnetic field vector measure spacecraft attitude and orientation while two onboard hydrazine monopropellent vernier thrusters correct orbital injection errors, increase perigee height as required to prolong GRS 2's orbital lifetime and maintain nominal solar orientation for the spacecraft's solar panel array while orienting onboard retarding potential analyser and mass spectrometer instrumentation to within ±60° from the satellite's flight direction during operational periods. GRS 2's data processing subsystem, comprising an encoder, two magnetic core memory units temporarily storing data prior to data either being recorded or transmitted in real-time, two tape-recorders and telemetry timer subystem; real-time PCM/PM telemetry and tracking beacon telemetry is transmitted at 137.290 MHz at 115 milliwatts and tape-recorded data is transmitted at 137.290 MHz at 1.5 watts both to Central German Ground Station, Wilheim, Bavaria under the management of German Space Operations Centre, Oberpfaffenhofen, FRG and additional telemetry receiving facilities at Kevo, Fort Churchill and Reykjavik while initial orbit tracking and data acquisition is performed by NASA's Space Tracking and Data Acquisition Network Stations with additional operational support of the spacecraft's atmospheric drag analysis experiment during GRS 2's orbital lifetime from NASA's Minitrack system. Onboard experimentation includes a mass spectrometer from Max Planck Institut fur Kernphysik, Heidelberg comprising an ion source and electrostatic lens system coupled to a mass analyser and detection and amplification system measuring upper atmospheric composition and particle density viewing outwards from GRS 2's cylindrical structure while a retarding potential analyser mounted on GRS 2's lower structure facing away from the Sun measures ion and electron energy distribution and total ion density at orbital altitudes, a boom-mounted impedance probe deployed from GRS 2's lower structure measures atmospheric electron concentrations and an onboard extreme ultraviolet spectrometer, each from Arbeitsgruppe fuer Physikalische Weltraumforschung, Freiburg, constantly observes the solar disc through GRS 2's solar-oriented solar cell array to measure flux, spectral distribution and spatial and temporal variations of extreme ultraviolet solar radiation. Earth's thermospheric neutral gas temperature, atmospheric molecular nitrogen concentrations and total atmospheric density are measured by the spacecraft's neutral atmosphere temperature instrumentation from NASA's Goddard Space Flight Center viewing outwards from GRS 2's cylindrical structure while precise observations of GRS 2's change in orbital period are utilised to

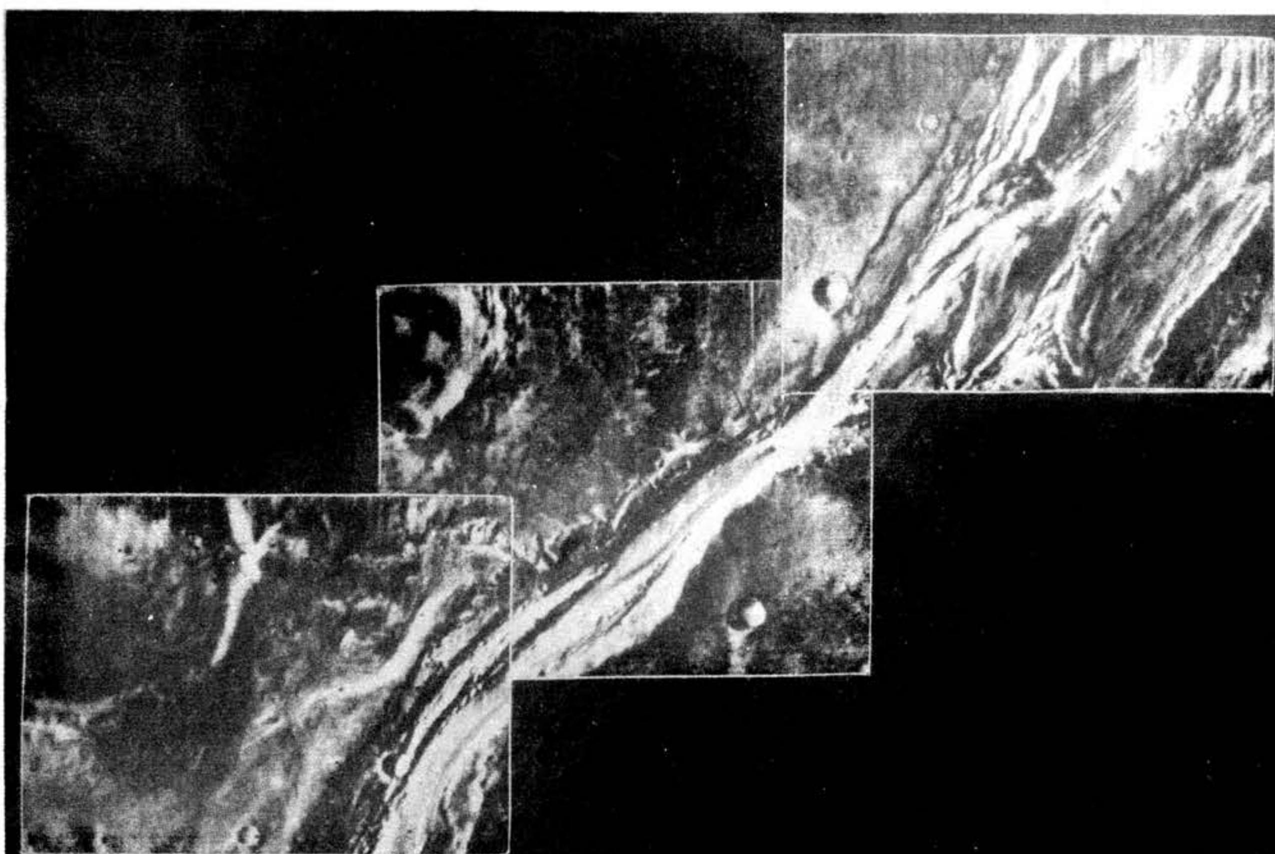
support studies of atmospheric density at perigee from analysis of atmospheric drag.
(12) Orbital data at 1972 Dec 25.7, Dec 25.9 and 1973 Jan 1.0.
(13) Capsule ejected from 1972-105A at about 1973 Jan 8.

Decays:
Explorer 41, 1969-53A, decayed 1972 Dec 23, lifetime 1281 days.

Amendments:
1972-10A, second orbit perigee is 35416, apogee is 35962, inclination is 0.2, period is 1429.9.
Titan 3C-18, 1972-10B, second orbit perigee is 35416, apogee is 35962, inclination is 0.2, period is 1429.9.
Cosmos 497, 1972-48A, lifetime is 16 months.

Satellite totals to 1972 December 31:

Origin	USSR	US	US/UK	Canada	Italy	France	Unknown	UK	Australia	ESRO	FRG	Japan	CPR	Total
Launchings	622	558	2	5	3	8	0	3	1	7	3	4	2	1218
Objects orbited	3170	3324	2	5	3	56	9	5	1	11	7	7	5	6605
Objects re-entered or decayed	2333	1228	1	0	3	14	1	1	1	4	0	0	0	3586
Objects on the Moon	38	111	0	0	0	0	0	0	0	0	0	0	0	149
Objects on Venus	16	0	0	0	0	0	0	0	0	0	0	0	0	16
Objects on Mars	6	0	0	0	0	0	0	0	0	0	0	0	0	6
Objects in geocentric orbit	785	1988	1	5	0	42	8	4	0	7	7	7	5	2859
Objects in heliocentric orbit	24	40	0	0	0	0	0	0	0	0	0	0	0	64
Objects in barycentric orbit	17	60	0	0	0	0	0	0	0	0	0	0	0	77
Objects in selenocentric orbit	9	7	0	0	0	0	0	0	0	0	0	0	0	16
Objects in areocentric orbit	2	1	0	0	0	0	0	0	0	0	0	0	0	3
Total in orbit	837	2096	1	5	0	42	8	4	0	7	7	7	5	3019



The best evidence yet that water once flowed on Mars. A channel thought to have been formed by running water in eons past is seen in this mosaic of 3 pictures of Mars taken by Mariner 9. 'Flow' of the ravine is northward, from lower left to upper right. This small segment of the channel is about 75 km (47 miles) in length and is located just north of the equator between Amazonis and Memnonia. The spacecraft took 7,329 pictures in mapping the entire surface of the planet during the period 13 November 1971 to 27 October 1972.

T 30

CORRESPONDENCE

Trans-Plutonian Planet

Sir, A. T. Lawton in his paper 'Planets Beyond Pluto?' [1] has used Brady's analysis [2] of perturbations to the orbit of Halley's Comet, as proof that a massive trans-Plutonian planet exists. However, since Brady's paper appeared, two further pieces of research have been done which cast some doubt on the validity of Brady's conclusions. Kiang [3] has examined the original records of the apparitions for Halley's Comet from 1456 onwards,and his revised dates for perihelion passage considerably reduce the residuals from which Brady inferred the existence of a trans-Plutonian planet.

Furthermore, Foss, Shawe-Taylor and Whitworth [4] at the Royal Greenwich Observatory conducted a photographic search for Brady's hypothetical planet during June and July 1972, and they detected no moving object brighter than their limiting magnitude of +16. The search covered an area which extended at least 3½° in every direction from Brady's predicted position.

Whilst the above research may not completely rule out the existence of a major trans-Plutonian planet, it does greatly reduce the circumstantial evidence for such a planet.

R. A. JAHN

1. A. T. Lawton, *Spaceflight,* **14**, 454, 1972.
2. J. L. Brady, *Pub. Astron. Soc. Pacific,* **84**, 314, 1972.
3. H. Kiang, *Mem. Roy. Astron. Soc.,* **76**, 27, 1972.
4. A. P. O. Foss, J. S. Shawe-Taylor, D. P. D. Whitworth, *Nature,* **239**, 266, 1972.

Will 'They' Look Like Us?

Sir, I must reluctantly agree with Mr. Spall's conclusions (*Spaceflight,* November 1972, p. 437) on the likely morphology of intelligent extra-terrestrials – just so long as we are not going to try and define intelligence. However, there is some evidence to suggest that the human form is not entirely suited to its present mode of life: backache is an example that springs to mind. One might expect other beings evolving towards a humanoid form to be somewhat more squat with shorter chests and more powerful legs than we have. Perhaps if the age of dinosaurs had not been brought to a close by a chance arrangement of continents and/or change of climate, the humanoid line might well have stemmed from the smaller bipedal dinosaurs who seemed to have developed all the mammalian characteristics apart from hair. The 'human' race might have been 20 million years ahead by now.

More profitable speculation might be directed towards the future. Already man (but mostly woman) has the technical means to alter body shape and appearance. With cosmetics and prosthetics it may soon be difficult to tell where the substance ends and the flesh begins.

An alien investigator faced by a drifting astronaut capsule with a lifeless crew might take some time to separate the three. If we meet other beings who are more technically advanced or better gadgetters than us, we might find that their essential 'humanoid' shape was completely masked or even replaced by their technological artifacts.

P. S. GOOCH

Sir, I basically agree with Mr. Spall's argument for the development of alien life, given an Earth-type environment. However, I believe that he has not taken into account the fact that creatures on Earth are constantly undergoing evolutionary changes and that evolution tends to be rather a change process. Mutations tend to form the basis for future generations, (e.g., flies mutating to resist DDT). Through mutative changes, the dolphin could, eventually develop the ability to use tools. The argument on the placement of sense organs is totally dependent on the nature of the environment, e.g., on a planet with food growing on a flat plain, the mouth and taste organs might be on the feet, and the breathing organs located higher on the torso in order to be in the atmosphere.

Finally, let us not forget two important points: (1) The probability that an alien world will have a totally different environment from that of Earth. (2) That statistical analysis show that the most predominant forms of life tend to be unicellular organisms or less, e.g. bacteria.

W. A. BASZTYK

Interstellar Flight Missions

Sir, The concept of non-return manned interstellar flight missions with the object of colonizing unknown planets outside the Solar System is romantically appealing but manifestly unrealistic. The only conceivable justification for such a venture would be the prospect of imminent doom for life within the solar system, when the project could usefully engage the efforts of the doomed during their terminal period.

The awesome difficulty of mounting an interstellar operation will ensure that those who engage in mounting it, if only indirectly through taxation, get some return for their investment. The scale of the operation will be orders of magnitude greater than the scale of corresponding undertakings within the Solar System, so we can confidently anticipate that the restrictions currently affecting Solar System exploration and colonization will apply with greater force. The following sequence of unmanned missions can thus be anticipated:

1. Extra Solar System probes with extensive instrumentation, self-repair capability, and transmission equipment.
2. Developments of (1) above with programmed search capability for selecting suitable planetary targets for fly-by exploration.
3. Developments of (2) above with planetary orbital and landing capability.
4. Developments of (2 and 3) above with return capability to Earth.

Depending on the relative state of progress with manned exploration and colonization of the Solar System, the following return mission manned programmes would be phased in at a suitable time:

1. Extra Solar System excursions to develop manned adaptation to very long period space flight.
2. Orbital missions around extra Solar System planets.
3. Landing missions.

Only when those missions have been accomplished in full and a careful assessment made of the feasibility and probable benefits of establishing a colony will such a mission be mounted. When it is appreciated that such an exercise must demonstrably benefit the Solar System, it is clear that the road ahead is long indeed. The colonists' starship is the end product of a series of ventures, of which the first must be tackled first.

S. W. GREENWOOD

(At the BIS Study Meeting in London on 13 January it was decided to launch an 18-month feasibility study of an unmanned space probe capable of reaching the nearer stars, taking account of the formidable problems of propulsion, structural engineering, electronics, radiation shielding, navigation, and other factors. The Study is being organised jointly by Mr. Alan Bond, a former propulsion engineer of Rolls-Royce (1971) Ltd., and Dr. Anthony Martin of City University, London. They have taken Barnard's Star, 6 light years away, as their target because it is thought to have a planetary system. For practical reasons they insist that the journey time must be limited to 30-40 years. The progress of this Study will be announced in due course. –Ed.).

NASA Standardization

Sir, According to Jean Meeus (*Spaceflight*, February 1973, p. 79) NASA announced on 1 May 1969 that Arabic numbers must be used for artificial satellites and space probes. I see, however, from my collection of mission patches that NASA has flown Apollos VII, 8, IX, X, 11, XII, XIII, 14, 15, 16 and XVII. If NASA's astronauts cannot conform to the rules, how can the rest of us be expected to do so?

J. M. OWENS

Film on the Moon

Sir, In the December 1972 issue of *Spaceflight* Mr. Phillip S. Clark – in a reference to a previous article by Mr. Falworth – stated that the Apollo 12 crew left two film cassettes on the Moon. This is not correct. They left one film magazine which had nothing on it.

My source for this information was a discussion some time ago with 'Pete' Conrad, mission commander and Richard Underwood, Technical Assistant to the Chief, Photographic Technology Division, Manned Spaceflight Center, Houston.

H. J. P. ARNOLD
Assistant to the Managing Director,
KODAK LTD.

Space Terminology

Sir, Mr. Meeus (*Spaceflight*, February 1973) seems to have made a few mis-interpretations about my previous letter (*Spaceflight*, October 1972) which I should like to elucidate for him.

Firstly, I fully acknowledged that 'circum-lunar orbit' was correct; my point was that everyone would know what 'lunar orbit' meant in the context in question, and that the issue was hardly worth raising.

Secondly, I did not state that the use of Roman numerals for satellites and space probes was preferable; merely acceptable. (Incidentally, Mr. Meeus, the word is 'numeration', not 'numerotation'). The news that NASA declared in 1969 that Arabic numerals must be used is a welcome to me as it no doubt was to Mr. Meeus, though it is news that apparently escaped a great many people besides myself. Furthermore, I doubt whether everyone will accept NASA's word as law on this matter.

Thirdly, the word 'apolune', as I wrote before, is in common usage (even by NASA; can THEY be wrong?) and is listed in glossaries of space terminology. Is it so heinous a crime to use it, rather than the clumsy 'aposelene'?

Mr. Meeus seems to be unduly concerned with trivialities. Who cares whether we write 'Mariner IV' instead of 'Mariner 4' or 'Earth orbit' rather than 'geocentric orbit?' By all means let us correct very misleading factual errors, but not waste any more space in the correspondence page over insignificant details.

S. A. BELL

(We regret that this correspondence must now close. –Ed.).

Pioneer 10

Sir, I am sure NASA would be most surprised if they found that Pioneer 10 was already on an interstellar trajectory, according to Mr. Graham's letter (*Spaceflight*, February 1973, p. 79). Prior to Jupiter flyby next December, Pioneer 10 will follow an elliptical heliocentric orbit with one of the foci at the Sun. After close approach to Jupiter, and after Pioneer 10's orbit has been perturbed by that planet, the spacecraft will

follow a hyperbolic orbit relative to the Sun and hence an interstellar trajectory. The spacecraft's 'solar system escape trajectory', reported in a number of publications, will only be followed after Jupiter flyby.

GEOFFREY FALWORTH

Will They Look like us?

Sir, I read with interest Mr. Spall's letter in the November 1972 issue of *Spaceflight,* concerning the probability that intelligent extraterrestrial beings might be humanoid. I would like to bring to light a short monograph by Robert Bieri that supports this argument. Titled 'Humanoids on other planets?', it appeared in the December 1964 issue of *American Scientist.*

Although the article presents only a rather general discussion of this topic, it is valuable as a source for further reading as it contains a number of excellent references concerning evolutionary selection which are applicable to exobiology. The article points out that the energy requirements for duplicating living system are fulfilled only by carbon and the high energy phosphate bond, This, coupled with the fact that it is most probable that a living system will arise in a liquid medium, gives a starting basis not far different from our own.

A living system developing from such a beginning and evolving within limits that are necessarily similar to our Earth's owing to time, energy and survival constraints, could very probably result in a conceptualizing being of humanoid form.

T. M SHARON

Astronautics History

Sir, The 'Astronautical History Society' suggested by Edward Peck (*Spaceflight,* December 1972, p. 480) underlines the historical awareness shown by the BIS in the pages of its publications, both in articles and reviews, many of which have been of considerable interest.

Yet both professional and lay interests in the full history of astronautics are apparent in efforts already underway. NASA has a modest historical programme, existent since 1959. Timely effort has already been invested in documentary archives, preliminary chronologies, and oral history interviews leading to published histories. The data base and preliminary detailing of much of what was not publicized about Apollo has already been accomplished. Several programme histories (Mercury, Vanguard) have already appeared, and others (Ranger, Gemini, Lunar Orbiter, etc.) are well along the way, as well as NASA institutional histories.

The Soviet Academy of Sciences also has an historical programme in its Institute of the Philosophy and History of Sciences under V.N. Sokolsky, which has done some excellent work on the early pioneers and less on the space age. Most helpful, however, are the historical groups where history-makers and historians mingle and collaborate. Among these are:

1. The History Commitee of the American Institute of Aeronautics and Astronautics, which sponsors an award annually for the best unpublished manuscript, and history programmes.
2. The National Space Club of Washington, D.C., the first U.S. history committee devoted to the history of rocketry and astronautics, sponsors the Goddard Historical Essay competition (now in 10th year).
3. The History of Rocketry and Astronautics Committee of the International Academy of Astronautics, which sponsors annual symposia at the international level with memoir and historical papers.

Missing as Peck suggests, is the 'historical group' of the BIS, soon to be forty years old.

Dr. EUGENE M. EMME

Water on Venus

Sir, I was very interested in one phase in Michael Marov's article on Venus as printed in the February issue of *Spaceflight:'........then it must be ascertained why water content in the Venerean atmosphere is at least a thousand times lower than on the Earth'.*

Was the *total* water content in fact measured by the Russian probes? (Venera 7). Finding that the water vapour content of the lower atmosphere 'was $<1\%$' does not mean the same thing. The top of the clouds is at a temperature of 30° or so below the freezing point of water (see Jukka Nikander's article, *Spaceflight,* April 1970,) so the presence of ice particles here has long been conjectured. Certainly early infra-red observations of Venus gave a curve that could have been interpreted as ice crystals [2].

An article by M. F. Norton [1] based on Mariner 5, and Venera 4, 5 and 6 probes still considered the question open enough to conjecture there could be enough water, as ice mainly to make an 800-1300 metre thick ocean covering for Venus if spread over its surface. (cf.2700m for Earth). This would give a ratio of H_2O: CO_2 on Venus of the same order as the 18:1 of Earth.

The article by Norton is interesting, with respect to this possible water, in advocating that a 'seeding' of specially developed plants could be made: these would be 'fluffy' enough to float at the ice/water level and fix the carbon from the CO_2, releasing the oxygen. Such a process could, argues Norton, cut the 'greenhouse' effect enough in time for the temperatures to drop sufficiently to allow the water to precipitate to the surface as oceans. The plant life would adapt, or others would be introduced to keep up with the changing conditions and could in time fix all the carbon and give Venus a habitable oxygen atmosphere. His object, of course, would be to make Venus habitable for Man.

I would not like to guess the 'life-ability' of a 100 bar surface pressure, but certainly his ideas seem worth investigating: hence my initial question as to whether the presence of water *in any form* is now completely excluded.

ALAN FARMER

REFERENCES

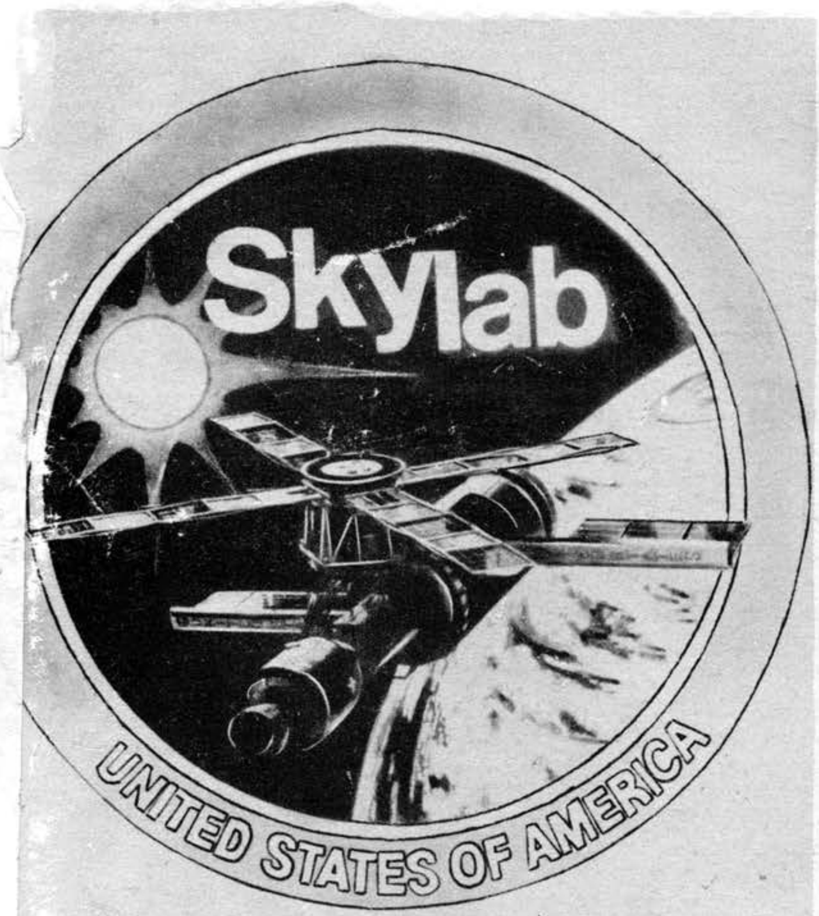
1. Norton, Matthew F, 'Making Venus Habitable, The Promise of Planetary Engineering', The American University, Washington, D.C. 1970.
2. Plummer, W. T., 'Infra-red Reflectivity of Frost & The Venus Clouds', *J.G.R.*, **74**, pp.3331-3336, 1969.
3. Pollack, J. B. and Sagan, C, 'The Case for Ice Clouds on Venus', *J.G.R.*, **73**, pp. 5943-5949, 1968.

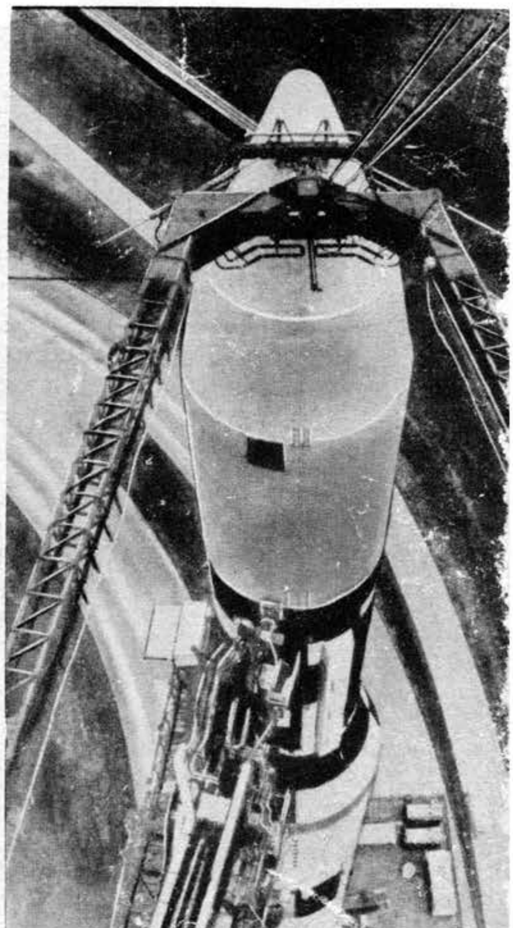
The Editor is interested in receiving further items of correspondence for possible publication in Spaceflight. They should be kept brief and precise, to avoid extensive editing.

SPACEFLIGHT

88905 КОСМИЧЕСКИЕ ПОЛЕТЫ № Т-7
(спейсфлайт)
По подписке 1973 г.

Vo ume 15 No. 7 July 1973





Published by The British Interplanetary

Editor:
Kenneth W. Gatland, FRAS, FBIS

Assistant Editor:
L. J. Carter, ACIS, FBIS

CONTENTS

COVER

SKYLAB IN TROUBLE. As we close for press plans were advanced for astronauts Charles Conrad, Joseph Kerwin and Paul Weitz in their Apollo CSM to attempt to salvage part of the Skylab mission. The orbital workshop had been successfully launched from the Kennedy Space Center at 18.30 BST on 14 May into a stable orbit some 270 miles (434 km) above the Earth but vibration during the launch phase appeared to have damaged the meteoroid shield and prevented proper deployment of the workshop's wing-like solar panels depriving the station of a large part of its electrical power. After three days in orbit solar radiation had heated interior compartments to 110 deg. F. *Top left,* Skylab emblem. *Right,* Skylab on the two-stage Saturn V launch vehicle, is transferred to Launch Complex 39B at Cape Kennedy. *Below,* Skylab's first crew Charles Conrad, Jr., Dr. Joseph P. Kerwin and Paul J. Weitz. Special arrangements have been made to cover Skylab operations in subsequent issues.

Photographs by Jacques Tiziou

SPACEFLIGHT

A Publication of The British Interplanetary Society

VOLUME 15 NO 7 JULY 1973 *Published 15 Jun. 1973*

MILESTONES

Apl

12 ESRO Council approves two new scientific satellites: HELOS (Highly Eccentric Lunar Occultation Satellite), devoted to X-ray astronomy, to be launched 1979; and ISEPS (International Sun-Earth Physics Satellites Programme), 'daughter' satellite, one of a pair of which NASA is to develop the 'mother'. Satellites are designed to be placed into orbit 'in tandem' from the same launcher in 1977.

16 Lunokhod 2 continues exploration of large fissure up to 100 metres deep in places running north-south for a distance of 16 km across basalt lava in eastern part of Le Monnier crater.

17-18 Lunokhod 2 passes southern extremity of fissure, skirting small boulders and craters to approach eastern boundary.

19 Soviets launch Intercosmos Copernicus 500 to investigate solar radiation and its influence on Earth's ionosphere. Instrumented by the USSR and Poland, with Czechoslovakian telemetry, satellite commemorates 500th anniversary of birth of Nicolaus Copernicus. Orbit is 202 – 1,551 km inclined at 48.5 deg to equator.

20 NASA launches Anik 2, second of two satellites for Canada's domestic communications satellite network, from Kennedy Space Center.

22 Lunokhod 2 ends fourth working day after examining fissure in southern part of Le Monnier crater. Fault structure is solid basalt that has split by tectonic forces. In studying magnetism of rock vehicle moved up to 500 metres from edge of fault and returned by same route; magnetism was greatest 150-200 metres from edge. Remote controlled rover has now covered a total distance of 36,200 metres since 16 January.

27 ELDO announces cancellation of Europa II programme after Ministers of France, West Germany and Belgium fail to agree to support the budget. Existing contracts run out in September.

28 *Tass* communique states that Salyut 2 has completed its flight programme having checked the design of improved on-board systems and carried out experiments in space.

May

7 NASA selects valley area of *Chryse* 19.5 deg N, 34 deg W, at northwestern end of 4,830 km (3,000 mile) long, 6,010 metres (20,000 ft) deep, Martian 'Grand Canyon' as prime target for first Viking lander in 1976. Rift system emerges into series of long channels which resemble dried-out river beds.

IS ANYONE OUT THERE?

EVIDENCE FOR THE EXISTENCE OF EXTRATERRESTIAL LIFE

By Dr. P. M. Molton *

Introduction

When we look up into the night sky we see stars. This rather obvious fact leads us to ask, how many? It turns out that in our Universe there could possibly be 10^{28} stars – the limit being set by the curvature of light under the sum gravitational attraction of all objects in the Universe. There could be more, but we would not be able to see them.

Hence, in looking for evidence of life in the Universe elsewhere than on the Earth, we are choosing a rather large subject. In fact we are choosing everything there is, to the 29th decimal place, the remainder being the Earth. Since we are unlikely ever to be able to cross the millions of light year gaps between galaxies, suppose we restrict our considerations to only our galaxy, assuming that the same arguments would be equally valid for any other.

This still includes some 135,000,000,000 stars. It has often been said that if we wish to know what this number of stars looks like, we should look at our sister galaxy, Andromeda.

There is more than just stars 'out there', of course. Interstellar space is filled with varying densities of dust and gas, charged particles, electromagnetic radiation, etc. Space is an *environment*, just like the Earth. And just like the Earth, it is unlikely that any one part is exactly like any other part. Space may have its deserts and its oceans.

What do we need for life?

Our main preoccupation is with life. This is not to say that an astronomer cannot get excited by interpreting photographic plates and discovering a new supernova, but surely the subject is more exciting for the possibility that other eyes may be watching the same event – eyes not based on the Earth?

We have little difficulty in looking around us and deciding what is living and what is not. The rock that falls down a mountainside has some of the properties of living things, but we would never for a moment class it as living. However, with any definition there are difficulties. *We* are living, and we can state that anything that in any way resembles us is also living. However, even using ourselves as a definition in this rather simple-minded way causes trouble, because life is so diverse. As Asimov has remarked [1], on life 'as we know it'...

'It flies, runs, leaps, crawls, walks, hops, swims, and just sits. It is green, red, yellow, pink, dead white and vari-coloured. It glows and does not glow, eats and does not eat. It is boned, shelled, plated, and soft; has limbs, tentacles, and no appendages at all; it is hairy, scaly, feathery, leafy, spiny and bare'.

To which we might add: 'it uses oxygen and does not use oxygen; it lives in the sea – at the top, middle and bottom– in light and in darkness; on mountaintops, deserts and arctic tundra; in boiling acid and 95% ammonia. It reproduces by fission, sexually, by seeds, spores...' The list could be extended for ever.

When we reach the chemical level, we *can* find something that all terrestrial life has in common .... the heredity material, nucleic acid, is common to all forms; so is the unit of structure, the cell (to a first approximation). Stating this in a form which allows some flexibility, 'Life can only exist where there is some chemical method of transferring structural information from one individual to the next generation. It can only exist where a simple structural unit separates it from the enviroment' Even this could exclude some living forms that are theoretically possible.

Besides the statement of what life needs chemically in order to exist, there is the problem of what does it live *on*? Although we can conceive of life existing in interstellar space [2], it is far more likely that it needs a planet for support. Also, of course, it needs a source of energy. We use the Sun, however indirectly, for all our energy. Other planets need other suns. Stars there are plenty – 135 billion of them in our galaxy alone. Are there any other planets?

Are there any other Solar Systems?

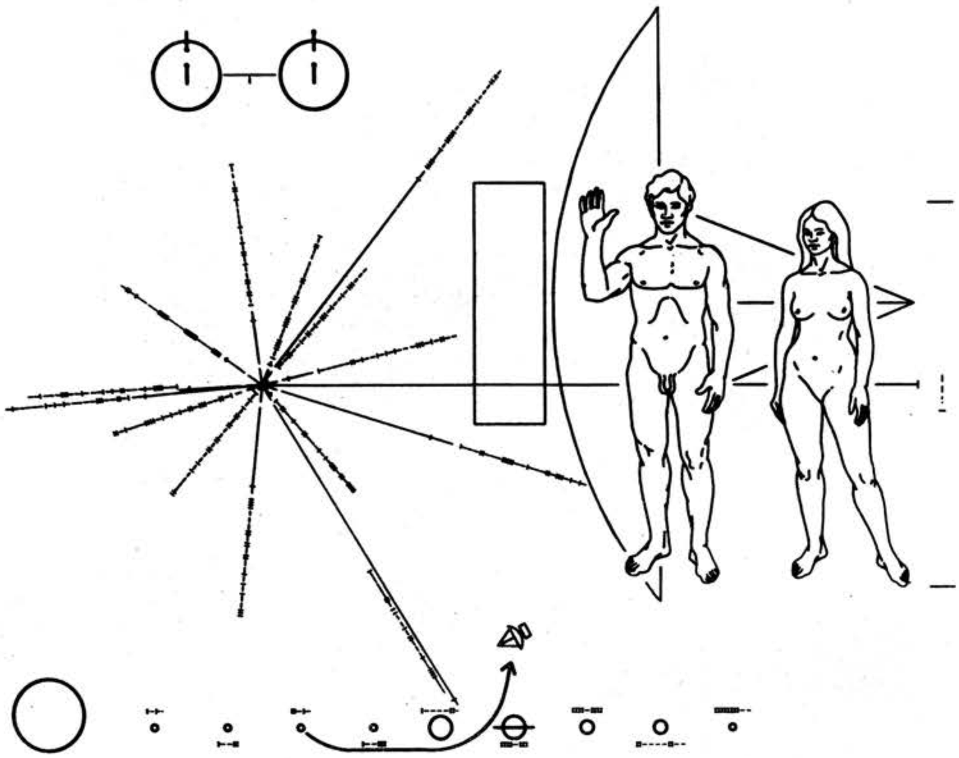
We are all familiar with the argument that as there are so many stars, there must be a great number of planets, even if planet formation is a very rare event. This is not a scientific argument. In a few words it states that 'There must be other planets of other stars because it would be silly if there were not'. What of more reliable reasons? Is there any evidence for the existence of other Solar Systems? There is such evidence.

It is possible, although very difficult, to measure the proper motions of some of the nearby stars – those within 50 light years or so, or about 3×10^{14} miles. Instead of travelling in a straight line, some of them follow a sine curve, i.e. they 'wobble' due to the attraction of some invisible body in orbit about them. Due to difficulties of measurement at these great distances, only very massive planets can be detected. The mass limit depends on the size of the star. One of the bodies would be almost a star in its own right, it is so massive, while the most famous of them, orbiting Barnard's star (a red dwarf a few light years from Earth) is scarcely twice the size of Jupiter, and must be considered as a planet. Where there are bodies the size of Jupiter which can only just be detected, there well may be bodies the size of Earth. Since these are in orbit around some of the closest stars to Earth, it would require a very unlikely statistical chance that these are the only ones in the galaxy [3]. But what if this unlikely chance has happened? After all, we are familiar with one-in-a-million chances happening every day. Perhaps the Earth *is* the only one of its kind.

To answer this question we need to know how planets can be formed. Over the years a variety of theories have been current, from the nebular hypothesis to the wandering star hypothesis. In simple terms, the Solar System (and by implication, all planetary systems) was formed either by the condensation of a cloud of gas, or by the near collision of the Sun with a passing star. If the nebular theory is correct, planets can form wherever there is a cloud of relatively dense gas and dust. If the grazing star theory is the right one, planets can only be formed on the very rare occasions when two stars have a near collision, and also when they have the correct relative masses, angular momenta, speed, etc. i.e. one per galaxy per aeon!

Fortunately for the theories of ubiquitous life, the nebular hypothesis appears to be the right one. Mathematical models and computer simulations [4] are about all that we have to go on, but the condensation of a cloud of gas would appear to produce both stars and planets. Not only that, but they give the same *types* of planets that we have in the Solar System – dense, small bodies like Earth and Mercury close to the Sun, gas giants like Jupiter in the middle, and again dense, small bodies (e.g. Pluto) farther out. In fact, there is some evidence for the condensation of stars, based on observations: Near the centre of the Orion nebula in 1947 there were five fuzzy objects. In 1954 there were seven [5]. These are believed to

* *Laboratory of Chemical Evolution, Chemistry Department, University of Maryland, College Park, Maryland 20742, U.S.A.*



Earth's message intended for other intelligent species, sent out aboard Pioneers 10 and 11. The plaque tells when the Pioneers were launched, from where, and by whom. Location of the Sun is shown by the intersection point of signals from 14 pulsars. Binary symbols show the frequencies of the pulsars today, and these could be used even a million years later to calculate the time of launch. The electron reversal in the hydrogen atom is shown to provide a measurable standard (its 21 cm radio wavelength) for both pulsar frequencies and the size of figures on the plaque. The man and woman are represented to scale with the spacecraft. The Sun and 9 planets are also depicted, as is the spacecraft's trajectory, leaving the third planet, Earth, passing Mars and swinging by the fifth planet Jupiter.

National Aeronautics and Space Administration

be stars in the making.

Hence, in answer to our question – yes, there *are* other planets, and there are stars to warm them. In the words of Pope [6]:

> 'Observe how system into system runs,
> What other planets circle other suns,
> What varied beings people every star'.

Thus, there most probably are other planets of other stars – but so what? Without life they are just so many lumps of rock, unless you take the attitude that one day we can reach them, in which case they may become valuable property for the use of our excess population! What of life? To answer this we need to have some idea of how *we* originated on this Earth.

Life on Earth

We are all familiar with the theory that life on Earth arose from the interaction of various inanimate chemicals, rather than by a specific Act of Creation [7]. How, by what means, using which chemicals? Short of using a time machine, we have to do the best we can by simulating supposed conditions on the primitive Earth in the laboratory. Usually this is done by taking a mixture of methane and ammonia, over water (the hydrogen and helium present when the Earth was formed having long ago evaporated into space). The gas mixture is then subjected to an energy source – sunlight, lightning radioactive particle beams, heat, thunder (shock waves), or in fact anything we can imagine, trying to find the source that actually was prevalent. The somewhat unattractive-looking products of these reactions are analysed for common biochemicals – in itself a very tricky job, as anyone who has analysed one of these products will realise. It is incredibly easy to let a hair drop into the reaction mixture, or touch a glass rod with a finger. Not quite as obvious as spitting into the flask, but the results are the same – biochemicals in abundance, but *not* from primitive Earth reactions.

However, assuming that great care has been exercised in the analysis, what do we find? The most surprising thing is that whichever energy source we use, the results are similar: Amino acids, some of them the familiar ones of the proteins in our own bodies [8]; nicotinic acid [9] – vital in our systems as part of the redox system; carbohydrates [10] very easily made from just formaldehyde and a little alkali; nucleic acid bases, the subunit of our heredity information transfer system. Just what we wanted, and just what we *are*. This is really stretching coincidence a bit too far. Of course, there is a lot of useless material synthesised also – amino acids that no living creature today has in its proteins (this is not to say that they never were); intractable tars, polymers... the amazing thing is not the useless things that are synthesised, but those which are required in our bodies as a part of our metabolic processes. The synthesis is *random* – any ratios of methane, ammonia and water can be used, virtually any source of energy. These results were not just derived from one experiment, either. The experiments have been repeated many times over the past 20 years, with every change and variation, with the most sensitive and reliable chemical methods, and the results have been the same.

Simple chemicals are not people, however correct they may be. They have to organise. Experiments made with condensing agents that could have been produced on the primitive Earth (cyanamide, condensed phosphates, etc. [11]), or simple heating, yielded condensed compounds – the forerunners of the proteins and the nucleic acids. Experiments

are now being done, taking some of the condensed materials, particles of clay, etc. to see if any of these systems have enzymic activity, or if reactions can be coupled to give more complex (i.e. 'biological') products [12]. Preliminary results suggest that some enzymic activity may be present.

However vague and incomplete the results – and no chemist can trace a couple of thousand million years of evolution in 20 years – they point undeviatingly towards a spontaneous generation of life on Earth [13]. Once. There is no process subject to the whims of a Creator (unless all processes are); given the conditions and the chemicals, the same reactions would take place anywhere in the Universe, since they follow the universal law. They follow the easiest paths. Would life evolve? This depends on whether one considers that life is a special force, or a function of chemical organisation. If the latter, life would evolve anywhere in the same way as it did on Earth. As yet we have no way of knowing.

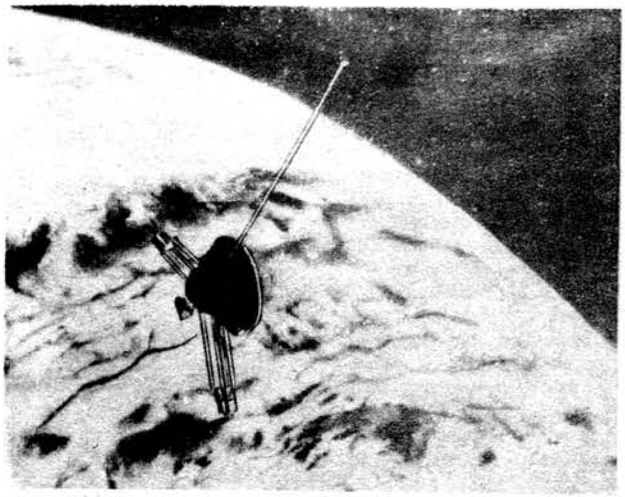
All this presupposes the existence of 'Earth-type' planets. That is, planets which are or were like the primitive Earth, with a lot of water, methane and ammonia. A planet like the Earth today, with 20% of free oxygen in its atmosphere, could not develop life. The simple chemicals which are the first step towards life would never form. They would be converted to carbon dioxide, water, and nitrogen. *We* have adapted to the presence of oxygen, and in fact need it for our existence. On the other hand, an oxygen atmosphere may be diagnostic for the presence of developed life on a planet, since we believe that the free oxygen in our atmosphere is the result of long ages of plant photosynthesis.

Life on other planets?

When the possible existence of life on 'Earth-type' planets is mentioned our thoughts immediately go outside the boundary, and ask about planets *not* like the Earth. Well, what of them? We are in the unfortunate position of having only one sample, ourselves, and having to make generalisations about a class – life. This is a fact that those who deny the existence of life elsewhere conveniently forget. A paper which did the same thing on some other subject would be curtly rejected by any journal, yet there are published papers which say, in effect, 'We are unique', or 'We are the only intelligent life in the Universe'. It sounds rather similar to the old cry: 'We are the centre of the Universe'.

In our Solar System, the planet Jupiter has conditions far removed from terrestrial, is the largest planet, and is relatively close. Hence it is a useful object for study. It has an atmosphere which is mostly hydrogen and helium, but there is also methane and ammonia, and there may even be water. To answer the question of the possibility of life there, it is necessary to do laboratory simulations similar to those which are done for the 'primitive Earth', since at present we cannot go near Jupiter. The situation may change if the proposed Jupiter/Saturn flyby is funded, later in this decade.

The sort of experiments that are done in the laboratory require some prior knowledge of Jovian conditions [14]. To the best of our rather inadequate knowledge there are several atmospheric cloud layers, which are composed of ammonia and probably water (the deeper ones), gradually changing to an hydrogen atmosphere of rapidly increasing density with depth, merging with a liquid hydrogen 'sea' and then with a solid/metallic hydrogen 'surface'. As the temperature increases rapidly with depth, any life on Jupiter would probably be restricted to the upper layers of the atmosphere (even theoretically, no life can exist at 2500°C!).



Artist's impression of Pioneer 10 over the surface of Jupiter. The spacecraft is due to make its closest observations on 3 December at the same time being accelerated by the giant planet's gravitation and orbital motion on its way out of the Solar System.

National Aeronautics and Space Administration

The simulation experiments were begun several years ago [15] and yielded the information that 'chemical evolution' (the formation of complex chemicals from simple ones) should in fact occur on Jupiter. This is the first stage in the generation of life. The chemicals produced are not the same as those produced under primitive Earth conditions, since the experiments were done in the absence of water. Instead of amino acids, nitriles were formed. However, when these are heated with water, similar amino acids are generated to those which are believed to have been formed on the Earth before life began. When we look further, for nucleic acid bases (purines and pyrimidines) we run up against the limit of present knowledge. It looks very much as though nucleic acid bases *are* formed, both from chemical reasoning and from circumstantial evidence, but no-one has actually yet pulled a nucleic acid base from a product of a simulated Jovian atmosphere [16]. Part of the circumstantial evidence is based on the ultraviolet absorption spectra of the products from simulated Jovian atmosphere experiments – these suggest the presence of aromatic compounds. In fact, under a UV lamp, they glow a bright blue. Some more of the circumstantial evidence doesn't concern Jupiter at all, but the interstellar dust, and meteorites. The dust contains some of the chemicals basic to life, as does the interstellar gas [17]. The whole of space as far out as we can see seems to be laden with 'biological' compounds. Meteorites have been shown to contain some pyrimidines [18], and they also contain unidentified compounds which are similar to those isolated from Jovian simulated atmosphere experiments [16]. If Jovian-type tars contain some of the heterocycles also present in meteorites, why not pyrimidines and purines? The same reactions occur in both places. Although this evidence is very teneous, it should not be long before some more substantial evidence is forthcoming.

Since the reactions which led eventually to life on Earth seem to occur also on Jupiter and may have occurred in the nebula from which meteorites were derived, why not on any planet where there is methane, ammonia, and energy? React-

ions are reactions – they don't care where they happen, if the conditions are right; they just happen. Jupiter is only of interest because it happens to be close and convenient. We are interested in life anywhere.

One of the unanswerable arguments against life elsewhere (at present) is that it is all very well to demonstrate that the raw chemicals necessary for life can be formed, or even that they will join together to form polymers, or even that the polymers can form things resembling living cells and doing some of the reactions associated with life – but would they *live*? This goes as well for Earth-type life as any other. We just don't know. All we can do is to say: 'There are the ingredients, all mixed and cooking. Will they walk or crawl out of there, or have we synthesised a corpse?' The old problem of the 'living force'! It seems that Jupiter may have water, in which case any life there would be based on the same type of Biochemistry as our own – mainly carbon, hydrogen, nitrogen, oxygen (and 22 other essential elements!). What if the water is frozen out or otherwise inaccessible? Could there be an ammonia-based life?

The Viability of other Biochemistries

This depends very much on the individual outlook. Some people, while they are quite prepared to acknowledge the likelihood of life elsewhere than on the Earth, would rather 'stretch' terrestrial life to virtually impossible extremes rather than consider the idea that life could be different [19]. True, Earth organisms can survive in hot acid, at the bottom of the oceans, in fact in practically any environment on, in or under the Earth – even under simulated Jovian conditions [20]. Terrestrial organisms have been shown able to survive under Martian conditions, or even under the heat of Venus, or in space... But indigenous life would not have to be like ours. In fact, it would be rather strange if it were. Our life is ideally adapted to terrestrial conditions, and it would show a surprising luck if other planets with widely different conditions had life based on the identical design.

In theory, other types of life are possible [21]. This is based on not very much evidence, since we know all too little about life anyway. However, structural materials (proteins), heredity information transfer materials (nucleic acids), energy materials (carbohydrates), etc. can be made, *in theory*, without the element oxygen. Nitrogen is a good substitute – in fact, there is a whole wide field of liquid ammonia chemistry that is every bit as large as the more familiar aqueous chemistry. Whether or not ammonia could form the basic solvent for life is anyone's guess. I think it could. Then, of course, hydrogen could be replaced by chlorine – again possible – and again there is a whole large field of organochlorine chemistry. Silicon-based life? Probably not, since carbon compounds would probably be present as well as silicon compounds, in any likely planetary surface, and carbon is much better suited for life support than is silicon, for several very good theoretical reasons. The important thing in this discussion is that other forms of life are possible, *in theory*. So is the existence of a large number of other planets. Hence, so is the existence of a wide spectrum of life on these planets.

Lest we should think that this is a new idea, born of our expanding technological civilization, Lucretius, over 2000 years ago, wrote: 'Granted, then, that empty space extends without limit in every direction and that seeds innumerable in number are rushing on countless courses through an unfathomable universe under the impulse of perpetual motion, it is in the highest degree unlikely that this Earth and sky is the only one to have been created and that all those particles of matter outside are accomplishing nothing. This follows from the fact that our world has been made by nature through the spontaneous and casual collision and the multifarious, accidental, random, and purposeless congregation and coalescence of atoms whose suddenly formed combinations could serve on each occasion as the starting point of substantial fabrics – Earth and sea and sky and the races of living creatures... You have the same natural force to congregate them in any place precisely as they have been congregated here. You are bound therefore to acknowledge that in other regions there are other earths and various tribes of men and breeds of beasts' [22].

So much for modern thinking!

We have now reached the stage where we can summarise what we have:

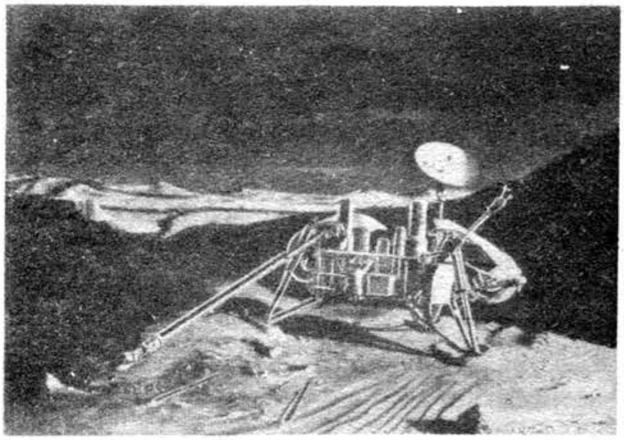
(1) Evidence for a boundless, or almost boundless, extent to the Universe and for an almost limitless number of stars.

(2) New theories for the formation of the Solar System, suggesting that it is a common phenomenon, plus evidence hinting at the presence of other such systems.

(3) Development of biochemistry to the point where some believe life will inevitably arise on any planet whose environment is similar to that of the Earth, as well as evidence that at least some steps towards the evolution of life occurred elsewhere [23].

Does Evolution always lead to Intelligence?

Nothing in the Universe is static. Even the simple chemicals on the primitive Earth gave way to polymers, and single cells, and larger and more diversified creatures, until eventually we look down on the aeons before us and pride ourselves on being at the top of the tree. We tend to forget that trees grow from the top. As on Earth, so it would be elsewhere, but



NASA's Viking spacecraft is due to arrive on Mars in 1976 to begin a chemical and biological examination of the surface. In this painting Viking's scoop takes its third sample of Martian soil. The antenna beams its findings towards a waiting Earth. The scene represents the best information, from Mariner and other spacecraft, that we have of Martian surface conditions.

TRW Incorporated

would evolution elsewhere necessarily have led to the development of intelligence? After all, we are a very recent event in the Earth's long history, appearing only in the last 2 million years of a 4-5 thousand million year story. We may surmise that survival pressure caused some animals to develop protective coloration, or teeth or claws, or just to grow bigger. We became more intelligent, able to think our way out of a situation, develop tools and weapons... always, the least intelligent were killed.

Why didn't we just develop claws or teeth, like all the others? Luck, or an inevitable result? Nobody knows. There may, on some planet somewhere be a race of supremely intelligent beings who have no desire to contact us or anyone else – but if *we* are typical, this is unlikely. We are aggressive, curious, and intelligent because we respond to evolutionary stress in such a manner as to tend to reduce the stress. There may be an equation which says, in effect, that the absence of stress can be equated with the absence of development... the idyllic world being also the dumb one. Or, the two factors may be unrelated. However, in us the development of curiosity and of intelligence seems to be related. Thus, our urge to explore is related to our ability to think. With others also? There is no way of knowing unless we undertake some very basic psychological research. Perhaps it is time that we did.

Would extraterrestrial intelligent life look like us?

It is strange that in most works of fiction, the extraterrestrial is either insect-shaped and totally evil, or human and benign. This somewhat overinflated view of ourselves could cause trouble if a meeting ever comes to pass.

There are reasons why we have the shape we do, why we walk on two legs and have little hair. There are also reasons why fish are streamlined and bears have teeth. The reasons depend on what they do. A bear shaped like a fish would be a sorry sight, and so would a man with fins instead of hands. Functional perfection for a way of life is a result of long adaptions, not chance, and the same process must occur on other planets.

NASA recently illustrated this by getting children to compete in designing a creature that could walk on the surface of the Moon. The vacuum on the Moon would cause it to have a very thick skin to prevent loss of valuable fluids; the skin would probably be highly polished to reflect some of the intense radiation from the Sun, and might be laden with heavy metals to absorb the higher energy particles. The transition from intense sunlight to deepest darkness on the Moon is abrupt, so the eyes would need to be extremely sensitive in darkness and equally good in bright light: this could be best achieved by use of multiple translucent eyelids, rather like the visors of the Apollo astronauts. For food, the creature would have to rely on the meagre amounts of carbon, nitrogen and water that would be found in the rocks – and would have a mouth full of molars to deal with this. With long legs for movement in low gravity over tall obstacles, and four of them (at least) for stability, the Lunar Horse is complete.

On Jupiter the same argument applies. Since there may be no surface and the lower depths of the atmosphere are very hot, the creature would float under its own built-in balloon, and would feed on organic compounds produced in electrical discharges in the upper atmosphere.

These descriptions could be carried on *ad infinitum*, but they serve to illustrate the point that extraterrestrial life will not be humanoid unless the particular planetary conditions are similar to terrestrial, and even then there could be alternative lines of evolution to that taken by Mankind.

An obvious example, here given in extreme form, is based on the fact that our eyes see visible light, which just happens to be the region where the Sun has its maximum output. Chance? No! What of a planet of an infrared star? If the planet supported intelligent life and a visitor from Earth arrived, the visitor would be visible because we emit heat (infrared) radiation. However, the planet would seem to be in total darkness to the human, and he would probably set up a searchlight or some similar source of illumination – which being of shorter wavelength than the ambient would have a similar effect on the indigenous life to strong ultraviolet on our eyes. Eyes would be blinded, vegetation would shrivel, etc. Not a very friendly start!

Now reverse the argument: Earth has a visitor from a planet whose star is an ultraviolet emitter; being unable to see, he sets up his light source, blinds a few officials, kills some plants. Our reaction would be one of panic, at the very least – and the intentions on both sides could be nothing but good. All because eyes evolve to use the region of the spectrum where the star has its maximum output.

For another example, what of speed? Just because our metabolism allows us to travel at a certain speed is no reason to assume that this is a universal constant. In fact, it isn't even true on Earth. Plants move at a rate of a few inches per year; the 'hare and the tortoise' is an old fable; the cheetah can travel in short bursts of up to 80 mph. When discussing the problem of extraterrestrial life, many authors have fallen into the trap of saying that since the ambient temperature on a given planet is very low (e.g. Pluto, at -230°C), then life is impossible there because reactions are too slow. This neglects the two facts that there are reactions which are fast at any temperature – we just have to choose the correct ones – and that there is no reason against 'slow life'. It is still life, even though it may not be very agile, by our standards. Conversely, what is wrong with the idea of a form of life that evolves faster than us because it *is* faster than us? Higher temperatures, or a high rate of mutation (such as on the hypothetical planet of an ultraviolet sun) would have this effect. This would lead to intelligence and an advanced civilisation that would be far ahead of us, even if it started at the same time.

Would it even think like us?

As with the body, so with the mind. We assume that all intelligent life more advanced than us must be benign, godlike – a mistake also made by the Red Indians of North America, the Tasmanians, the Hawaiians, Australian aborigines, etc. Why? Even with *ourselves* as an example, we come to all the wrong conclusions. Is there intelligent life on *Earth*?

For one example, consider a planet where the clouds never clear – quite a likely event, and there would be no impediment to the development of intelligence in this. Next suppose that our terrestrial explorer arrives, sets up a form of communication, and tells the native: 'We come from the stars'. Through the civilisation of this alien, he has been taught that his race is all there is, his world is all there is – surrounded by clouds, there is no more to see. Astronomy and radio-astronomy would never have developed: What is the point of looking for what you know cannot be there?

Galileo and Copernicus had this difficulty. This alien could be the mental twin of ourselves, but with different development would be beyond understanding. How different

would we expect an inhabitant of Jupiter to be? The fate of our terrestrial astronaut would most likely be that of lunatics everywhere.

NASA's Committee on Long-Range Studies had the following to say: 'Anthropological files contain many examples of societies, sure of their place in the Universe, which have disintegrated when they have had to associate with previously unfamiliar societies espousing different ideas and different life ways; others that survived such an experience usually did so by paying the price of changes in values and attitudes and behaviour.

Since intelligent life might be discovered at any time *via* the radio telescope research presently under way, and since the consequences of such a discovery are presently unpredictable because of our limited knowledge of behaviour under even an approximation of such dramatic circumstances, two research areas can be recommended:

(1) Continuing studies to determine emotional and intellectual understanding and attitudes, and successive alterations of them if any, regarding the possibility and consequences of discovering intelligent extraterrestrial life.
(2) Historical and empirical studies of the behaviour of peoples and their leaders when confronted with dramatic and unfamiliar events or social pressures...' [24].

This assumes the contact to be with a benign civilisation – or at least, a well-meaning one!

Benign or not?

We equate civilisation with the concept of 'goodness'. This is nothing short of silly. Civilisation as we define it is a form of society, which can include the society of the ant – which, incidentally, was on Earth long before we were – and societies usually look out first for their own interests. Obviously! This is the supremely logical approach. To take an example from our own society, who in a business does not view approaching competition with apprehension? And who, if he could, would not try to send it elsewhere or divert it or stop it? We all think in terms of welcoming visitors from the stars: perhaps we are only still in existence because (a) they don't know that we exist, or (b) they cannot cross space to get to us, or (c) we are totally insignificant.

For point (a), we have been sending radio signals into space, inadvertently or deliberately, for over a century, and even we could probably detect our own signals from a couple of light years away. For (b), this could change at any moment. Even if faster than light travel *is* basically impossible, as many people believe, we already know of three systems which would be able to take *us* across interstellar space – the photon rocket, the ion rocket, and the interstellar ramjet. At light speed (or almost), a journey of several years is no great difficulty. Finally, the premise of point (c) could change very rapidly if we continue with our present technical advance – although with present cuts in the research grants in the most advanced countries, our progress is probably coming to a halt.

What of our reaction to a friendly contact? Not the 'welcome, Brother!' fiction that we fondly believe of ourselves. Suppose, clearly and unmistakably, there comes from a nearby star a message that translates unequivocally as 'Hello, we're friendly'. Would we immediately make a courteous and friendly reply? No. Our military representatives would caution us, 'Beware, it may be a trick...' A story that is all too common in the international situation on Earth today – we would try to find ways to get them before they get us... A friendly reply would only be sent if there were no possible threat to our society, and how would we possibly know if this were true? Let us not expect of others what we are not capable of doing ourselves.

Freeman Dyson expressed these sentiments [25].

'Intelligence may indeed be a benign influence, creating isolated groups of philosopher-kings far apart in the heavens and enabling them to share at leisure their accumulated wisdom. On the other hand, intelligence may be a cancer of purposeless technological exploitation, sweeping across the galaxy as irresistibly as it has swept across our own planet'. Assuming interstellar travel at moderate speeds, he said, 'the technological cancer could spread across a whole galaxy in a few million years, a time very short compared with the life of a planet. What is there may conform to our moral sense or it may not... It is just as unscientific to impute to remote intelligences wisdom and serenity as it is to impute to them irrational and murderous impulses. We must be prepared for either possibility and conduct our searches accordingly'.

What should we do?

Since we do not *know* what there is in space, we should take steps to find out. Mankind is at present mentally patting itself on the back that one section of it has reached the Moon a few times. Now, that nation is cutting the space budget, implying, 'Well, we did it. Now we can all go home'. The other nations of the world didn't even try, with one notable exception. With all the radio noise blasting out of the Solar System, with space probes escaping into interstellar space, this is no time to rest on our laurels. Maybe space is devoid of intelligence, but dare we take the risk?

What we *can* do, that on which we have gained so much already, is to think, and explore. In our Solar System there could be life, although the chances are not very great. By exploring the other planets on our own doorstep, so to speak, we would gain knowledge on which we could extrapolate the chances of there being life in other systems elsewhere.

However, it is very much to be doubted that we will do anything – this was said about the requirements for funding of a radio telescope to listen for signals sent to us from other civilisations, and it is equally true of other projects [26].

'We haven't grown up to it. It is a project which has to be funded by the *century*, not by the fiscal year. Furthermore, it is a project which is very likely to fail *completely*. If you spend a lot of money and go around every 10 years and say, 'We haven't heard anything yet', you can imagine how you make out before a congressional committee'.

Sad, but true. Yet if enough people were to ask what was being done to protect them from possible dangers from outside, something could be done. The answer at present is invariably, 'We have enough problems on our own Earth, without looking elsewhere', said in a tone of polite dismissal, as to one of low mental capacity.

Conclusion

The author sincerely wishes that some of the conclusions reached here will prove totally wrong.

This paper completes the series which includes papers referenced 13, 14, 21, together with 'Limitations of terrestrial life', P. Molton, Spaceflight, **15**, 27-29 (1973).

REFERENCES

1. Isaac Asimov, 'View From A Height', Lancer Books, N.Y. p. 56, 1963.
2. Carl Sagan, 'Interstellar Organic Chemistry', *Nature,* **238**, 77-80 (1972).
3. Walter Sullivan, in 'We Are Not Alone', McGraw-Hill, N.Y. pp. 49-52, 1966.
4. S. H. Dole, 'Computer simulation of the formation of planetary systems', *Icarus,* **13**, 494-508, (1970).
5. Reference 3; opposite p. 7.
6. Alexander Pope, in 'An Essay on Man', Epistle I. lines 25-27.
7. R. Buvet and C. Ponnamperuma, eds. 'Chemical Evolution and the Origin of Life. I Molecular Evolution', North Holland Publ. Co. Amsterdam, 1971.
8. A. Bar-Nun, N. Bar-Nun, S. H. Bauer and C. Sagan, 'Shock synthesis of amino acids in simulated primitive environments', *Science,* **168**, 470-473 (1970).
9. N. Friedmann, S. L. Miller and R. A. Sanchez, 'Primitive Earth synthesis of nicotinic acid derivatives', *Science,* **171**, 1026-1027 (1971).
10. A. G. Cairns-Smith, P. Ingram, and G. L. Walker, 'Formose production by minerals: Possible relevance to the origin of life', *J. Theoret. Biol.* **35**, 601-604 (1972).
11. S. Chang, J. A. Williams, C. Ponnamperuma and J. Rabinowitz, 'Phosphorylation of uridine with inorganic phosphates', *Space Life Sci.* **2**, 144-150 (1970).
12. S. W. Fox, 'Self-ordered polymers and propagative cell-like systems', *Naturwissenschaften,* **56**, 1-9.(1969).
13. P. Molton, 'Spontaneous generation and chemical evolution', *Spaceflight,* **14**, 187-192 (1972).
14. P. Molton, 'Exobiology, Jupiter, and Life', *Spaceflight,* **14**, 220-223 (1972).
15. F. Woeller and C. Ponnamperuma, 'Organic synthesis in a simulated Jovian atmosphere', *Icarus,* **10**, 386-392 (1969).
16. P. Molton and C. Ponnamperuma, 'The probable existence of aminonitriles in Jupiter's atmosphere', Presented at the Middle Atlantic Regional Meeting of the American Chemical Society, Washington, D. C. Jan. 1973.
17. D. M. Rank, C. H. Townes and W. J. Welch, 'Interstellar molecules and dense clouds', *Science,* **174**, 1083-1101 (1971).
18. C. E. Folsome, J. Lawless, M. Romiez and C. Ponnamperuma, 'Heterocyclic compounds indigenous to the Murchison meteorite', *Nature,* **232**, 108-109 (1971).
19. R. A. Horne, 'On the unlikelihood of non-aqueous biosystems', *Space Life Sci.* **3**, 34-41 (1971).
20. P. Molton and C. Ponnamperuma, 'The survival of common terrestrial microorganisms under simulated Jovian conditions', *Nature,* **238**, 217-218 (1972).
21. P. Molton, 'Terrestrial biochemistry in perspective: Some other possibilities', *Spaceflight,* **15**, 139-144 (1973).
22. Reference 3, p. 7.
23. Reference 3, p. 24.
24. Reference 3. pp. 278-279.
25. Reference 3, p. 280-281.
26. Reference 3, p. 234.

SUPERRELATIVISTIC INTERSTELLAR FLIGHT

OR CRACKS IN THE LIGHT BARRIER

By Joseph W. Morgan, F.B.I.S.*

Introduction

In a few decades we will have explored our back yard, the Solar System [1]. From Pluto we will gaze across formidable reaches to distant suns. Star-faring will become the major technological challenge to civilization. Visiting Sol's neighbours will be no mean task. The interstellar gulfs are so vast as to make the speed of light seem like a feeble crawl.

Marginal Adequacy of Conventional Rocketry

Traditional rocketry consists of hauling along large quantities of mass, expelling it aftwards at the highest possible velocity, and thus achieving forward thrust via Newton's second law. Even the ideal case of an optimized multi-stage photon rocket powered by a matter/anti-matter annihilator is marginally adequate for interstellar flight. Titantic quantities of energy are required to accelerate a starship to relativistic velocities. Each additional increment of velocity requires a greater expenditure of energy than the previous one due to the increase of mass with velocity.

$$m(v) = \frac{m_o}{\sqrt{1 - (v/c)^2}}$$

m = relativistic mass
m_o = rest mass
v = velocity
c = speed of light, 186, 282.3960 mi./sec. ±3.6 ft./sec.

Several ideas have been put forth to obviate the need for carrying along large amounts of mass to be used as ejecta. Among these are the interstellar ramjet, propulsion by means of interaction with galactic electromagnetic fields, gravitational catapults using general relativistic effects of very massive rotating bodies, power transmission via laser beam, and fuel depots in space [2].

All of these concepts share some of the limitations of conventional rocketry – exorbitant energy requirements, and subluminous velocities. In addition to the very challenging engineering problems of interstellar flight, there exists the allegedly inpenetrable light barrier blocking the way to travel at superrelativistic velocities, that is velocities greater than that of light. I submit that there are at least 3 cracks in the light barrier.

Effective Velocity

The controversy over the twin paradox has raged, often very heatedly, for decades [3]. Many have found the asymmetrical aging predicted by relativity theory unpalatable, but the recent experiment conducted by Keating and Hafele, in which a highly accurate caesium clock was flown around the Earth and compared to a stationary clock has experimentally confirmed that the moving twin ages less than the stay-at-home. This together with the recent CERN muon-

moment experiments, seems to leave little doubt as to the validity of asymmetrical aging. With regard to starflight, the crux of the matter is this: a period of time experienced by astronauts, t', is related to a period of time experienced by the Earth-bound, t, by

$$t' = t\sqrt{1 - (v/c)^2}$$

The effective velocity, v_{eff}, the astronauts experience is

$$v_{eff} = \frac{s}{t'} = \frac{s}{t\sqrt{1 - (v/c)^2}} = \frac{v}{\sqrt{1 - (v/c)^2}} \qquad s = \text{distance travelled.}$$

The effective velocity can range from zero to infinity. For example, to the occupants of a starship travelling at .99c, they cover a distance of one light year in about .14 years of ship time, giving them an effective velocity of 7c. An Earth-bound observer sees them cover this distance in a little over one year with v = .99c.

Therein lies one of the pitfalls in this method. Although the astronauts experience $v_{eff} > c$, the civilization that mounted the expedition must wait years for the return of the explorers. The other difficulty is the previously mentioned problem of energetics that occurs when a starship must be accelerated from rest to relativistic velocities where the time dilation effect becomes significant.

Tachyons

Several papers [4, 5, 6] have recently appeared in which physicists have shown that if one hypothesizes a particle that always travels faster than light (and thus avoids the infinite energy light barrier) there is actually no conflict with the theory of relativity. This new class of particles has been called tachyons to distinguish them from luxons (photons and neutrinos) which always travel at light speed, and tardyons which always travel at $v < c$. The total energy of a body is given by

$$E = mc^2 = \frac{m_o c}{\sqrt{1 - (v/c)^2}} = \frac{m_o c}{i\sqrt{(v/c)^2 - 1}} \qquad i = \sqrt{-1}$$

For a tachyon $(v/c) > 1$ and the denominator becomes imaginary. An imaginary mass m_o will yield a real energy. Note the peculiar property that energy decreases with increased velocity, and that *c* is the limiting lower velocity. Note too the other velocity extreme. At infinite velocity the total energy becomes zero.

Tachyons appear to be theoretically possible and therefore probably exist or can be created. Experimentalists have searched for them in nuclear reactions but as yet without success. Possibly charged tachyons are discoverable by the Cerenkov radiation they are expected to emit. Going from the microscopic to the extragalactic realm, quasars 3C279 and 3C273 appear to be exploding at faster-than-light velocities. Has the violent release of energy in an exploding quasar created tachyonic matter, or are the velocities only apparent?

If tachyons exist, how do we detect them? How do we generate beams of them for interstellar communication? Is there a quasi-real time galactic communications network in operation, using tachyons instead of photons? Do more advanced civilizations use radio only for short-range communications? Is it possible to turn a tardyon astronaut into a tachyon astronaut? Present theory still separates the two realms with the light barrier.

Little is known of tachyons, even whether they exist or not, but there is certainly a great potential in this field for interstellar flight and communications.

Black Holes [8]

The gravitational distortion of spacetime may offer a method of fast interstellar travel. Black holes, predicted by Oppenheimer in 1939, were probably discovered by the *Uhuru* Small Astronomy Satellite launched in 1970. The X-ray source Cygnus X-1 appears to be a black hole/B supergiant binary system.

According to current astrophysical theory, spherically symmetrical stars with masses greater than 1.4 solar masses will totally collapse at the end of their evolution. The outward pushing forces of the fuel-depleted star are overwhelmed by gravity, and the star collapses to a singularity, a point of infinite density and infinite spacetime curvature, surrounded by a region called a black hole, within which the force of gravity prevents photons, and everything else for that matter, from escaping.

Matter falling into a conventional black hole would be ripped asunder by tidal forces and ultimately reduced to the point where the end product would be determined solely by the infalling matter's charge, mass, and angular momentum. Any spacecraft falling into a black hole would suffer this fate. Or would it?

Consider the more realistic case of a nonsymmetrical collapsing star. Penrose's Theorem states that for non-symmetrical stellar collapse, once a star has collapsed within its gravitational radius, no deformations can prevent the formation of a singularity. However, infalling matter may avoid the singularity. The deformed black hole may act as a wormhole, sweeping the matter to a new, unknown point in spacetime, possibly even to another universe. A third type of collapsed object is a naked singularity, where the singularity is not embedded in a black hole and therefore, can be seen by an external observer.

As would-be interstellar astronauts, the second type of object is of great interest. Here we have the possibility of short-cuts through a multiply-connected universe. Is this the long-heralded 'space warp' of science-fiction? Might a spacecraft purposefully enter this type of black hole, survive the tidal forces, and fly through a wormhole in spacetime and emerge safely at another point?

Closure

Present methods of space propulsion hold dismal prospects for interstellar flight. This is not to say they are impossible, but perhaps impracticable. Totally new concepts are needed for deep space travel. Clues are likely to come from the esoteric realms of relativistic astrophysics where Einstein's theories seem to fail under extreme conditions.

It is interesting to note that if one plots a speed trend curve it goes asymptotic by 1982. In fact, science-fiction writers have been consistently too conservative in predicting the technological future. At any rate real progress in this

**Michelson Laboratory, Naval Weapons Center, China Lake, California 93555, U.S.A.*

area will begin, as always, with scientific speculation. A breakthrough into the realm of practical interstellar flight at superrelativistic speeds would not merely be a quantum jump in astronautics but a bound-free transition. *Ad astra!*

REFERENCES

1. This analogy is conservative by many orders of magnitude. I have always considered references to regions beyond near-Earth orbits as 'deep space' as a little provincial.
2. E. F. Mallove, R. L. Forward, ***Bibliography of Interstellar Travel and Communication*** – 1972, (Hughes Research Laboratories Report No. 460, November 1972).
3. L. Marder, *Time and the Space Traveller,* (Fakenham, 1971).
4. O. M. Bilaniuk, E. C. G. Sudarshan, 'Particles Beyond the Light Barrier', *Physics Today,* May 1969, 143.
5. R. G. Newton, 'Particles that Travel faster than Light?', *Science,* No. 3925, 1569.
6. G. Feinberg, 'Possibility of Faster-than-Light Particles', *Physical Review,* **159**, 1089.
7. Use of an imaginary number does not imply the quantity so represented is also imaginary.
8. (a) R. Ruffini, J. Wheeler, 'Introducing the Black Hole' *Physics Today,* January 1971, 30; (b) K. S. Thorne, 'The Death of a Star', *The Griffith Observor,* November 1970, 226; (c) K. S. Thorne, 'Nonspherical Gravitational Collapse: Does It Produce Black Holes?', *Comments on Astrophysics and Space Physics,* 2, September-October 1970, 191; (d) R. Penrose, 'Black Holes and Gravitational Theory', *Nature,* **236,** 21 April 1972. 377.

REVISED HEAO PROGRAMME

NASA is devloping plans for a scaled-down version of the High Energy Astronomy Observatory (HEAO) – a project which has been suspended since January for budgetary reasons. Preliminary planning calls for three flights between 1977 and 1979 to study some of the most intriguing mysteries of the Universe – pulsars, black holes, neutron stars and supernovae.

While these plans are progressing well, it is expected that HEAO will remain in a state of suspension, with only minimum expenditures of funds, for at least a year. Under the revised scheme, scaled-down observatories will be launched by smaller rockets and carry fewer scientific instruments. In addition, much of the equipment will come from designs developed for other satellites which have already flown.

The HEAO programme was originally created to place into space scientific instruments capable of performing high sensitivity, high-resolution studies of celestial X-rays, gamma rays and cosmic rays. These phenomena cannot be studied from Earth because of the obscuring effects of our atmosphere. They have been observed previously only by sounding rockets and balloons, and by small satellites which do not possess adequate energy resolution or sensitivity for the very low fluxes being studied.

Information returned by HEAO will help provide a better understanding of the nature and origin of such high-energy astrophysical phenomena. This knowledge, in turn, may provide clues to some of the 'newest' and most mysterious objects in the Universe. They include:

Pulsars and Neutron Stars: Discovered in 1967, pulsars emit radio signals whose pulsations are extremely precise. The bulk of available evidence suggests that pulsars may be fast-spinning neutron stars. These are compact bodies of densely packed neutrons (atomic particles having no electric charge), believed to form when a large star burns up its fuel and collapses. Containing the mass of a star in a sphere 10 miles in diameter, they are so closely packed that a spoonful of material from the centre would weigh a thousand million tons.

Black Holes: Believed to be the final stage in the collapse of a dying star. The star's material is so densely packed – even more so than a neutron star – and the gravitational force so great that even light waves are unable to escape from the surface of a black hole. They have been hypothesised but never seen.

Quasars: Astronomers are still baffled by the nature of quasars, but many believe that among observable objects they are the most remote in the Universe. They look like stars when viewed through an optical telescope, but emit more energy at radio frequencies than the most powerful galaxies known. According to calculations, if they are as distant as many astronomers believe, the total amount of energy emitted by a quasar in one second (10^{47} ergs/sec) would supply all of Earth's electrical energy needs for a thousand million years.

Radio Galaxies: Located on the fringes of visibility, they emit radio waves millions of times more powerful than the emissions of a normal spiral galaxy. No one knows what these peculiar galaxies are. Several of them broadcast with such power that a sizeable fraction of the nuclear energy locked up in their matter must be going completely into the production of radio waves.

Supernovae: A supernovae is a large star at life's end, whose final collapse is a cataclysmic event that generates a violent explosion. Materials of the exploded star blown far into space mix with the primeval hydrogen of the Universe. Later in the history of the galaxy, other stars are formed out of this mixture. The Sun is one of these stars; it contains the debris of countless others that exploded before the Sun was born.

There is a strong evidence that supernovae (exploding stars) and pulsars are X-ray sources at some time in their history, and X-rays have been observed from some radio galaxies and quasars.

As originally planned, HEAO was to be a 9,500 kg (21,000 lb.) 9 metre (30 ft.) long spacecraft to be launched by a Titan 3C rocket into a 375 km (230 mile) orbit from Cape Kennedy. Four launches were planned, beginning in 1976. The first two spacecraft, HEAO-A and HEAO-B, were to have performed an all-sky survey of X-ray, gamma-ray and cosmic ray radiation; each was designed to carry 6 tons of instruments, with total observatory weight in orbit about 10 tons.

The third and fourth spacecraft were planned as launches from the Space Shuttle, which will be operational in 1980. One of the craft would have carried three X-ray telescopes with specialised detectors to perform detailed measurements.

REFLECTIONS ON CE

By Boris Belitzky*

Fact and Fiction

A film that drew packed houses in Moscow was Eric Denicken's screen version of his book *'Chariot of the Gods'.* Young and old alike would emerge from the cinemas speculating heatedly about the possibility of extra-terrestrial beings having visited our planet thousands of years ago. But despite considerable public (mostly youthful) excitement over the film, it had little, if any, impact on the steadily growing body of Soviet scientists with a genuine interest in the problems of extra-terrestrial life. Indeed, most of the artefacts presented by that West German writer as evidence of 'extra-terrestrial visitations' are dismissed by scientists as being utterly irrelevant to that problem.

A typical instance is the skull of an animal that roamed the Earth thousands of years ago, which is claimed by Denicken in both his book and film to have a 'bullet-hole' in it. The skull in question was found some years ago near Odessa. The alleged 'bullet-hole' – a careful study has since revealed – was made by a variety of shell-fish capable of boring orifices of regular shape.

As for the images of figures purported to be wearing 'space suits', these have in many cases turned out to be pictures of ordinary human beings in ritual masks and costumes.

Such, alas, has been the fate of most of the artefacts claimed to be related to visits by extra-terrestrial beings at some time in the distant past. Genuinely scientific examination has disposed of them as either wishful thinking, or scientific incompetence, or simply fraud.

A few days ago I had the opportunity to examine a vast collection of such artefacts on slides belonging to the science-fiction writer Alexander Kazantsev. Although Kazantsev must be given credit for having first suggested that the Tunguska Meteorite was a spaceship from another world that had exploded on approaching the Earth (a suggestion that did much to stimulate scientific studies of this phenemenon†) his collection of 'visitation artefacts' falls largely into the same category as Denicken's.

The Soviet radio-astronomer Iosif Shklovsky, when shown such artefacts, aptly quoted the ancient proverb: 'The man who eagerly awaits the arrival of a friend should not mistake the beating of his own heart for the thumping of hooves of the approaching horse...'

But while most scientists dismiss the far-fetched claims about 'extra-terrestrial visitations', there is a genuine scientific interest in the problem of radio communication with civilisations other than our own. In fact, we are at this moment witnessing the birth of a new area of science that has come to be known as CETI – Communication with Extra-Terrestrial Intelligence. Only a few years ago the very idea of communicating with other intelligencies belonged to the realm of science fiction. Not so today. Advances in radio-astronomy, biology, computer science, and communications technology – not to mention other related fields – have brought us to the stage where observation and direct experiment have become possible.

CETI is a very broad problem, with many aspects branching out into diverse fields of learning. Many of these aspects were discussed at length at the first Soviet-American conference on communication with extra-terrestrial intelligence.

This conference, which I was fortunate to attend, took place in September 1971 at the Byurakan Astrophysical Observatory in Soviet Armenia. And the list of participants read like a scientific Who's Who!

Soviet CETI Projects

The conference made possible a broad exchange of views on CETI, putting all the aspects of this complex problem in their proper perspective and enabling scientists to map out the main avenues of further studies in this field.

For one thing, the conference agreed that the promise of contact with extra-terrestrial civilisations was sufficiently high to justify initiating a variety of programmes of searching for intelligent signals from outer space.

This is one direction in which Soviet scientists are now working. One of their projects is headed by Professor Vsevolod Troitsky, a deputy director of the Radiophysical Institute in Gorky. With receiving stations stationed far apart (in the regions of Murmansk, Gorky, the Ussuri territory, and the Crimea), his team have been monitoring radio pulses of 3 to 50 cm. wavelengths.

Such spacing of the receiving stations makes it possible to rule out all pulses due to local radio interference and to concentrate on those that are registered by all the stations simultaneously and are hence global in character.

A valuable by-product of Troitsky's work has been the establishment of the geomagnetic and solar origin of some of the pulses.

Another project is being pursued by Dr. Nikolai Kardashov, a brilliant young astrophysicist of the Institute of Space Research, and Dr. Lev Gindilis, a radio-astronomer of the Shternberg Institute, who has devoted himself almost entirely to CETI work. Both of them spent part of the summer last year in the mountains of the Caucasus with portable apparatus specially designed for CETI work.

CETI research was also discussed at a conference arranged by the Radiophysical Institute in Gorky last year.

CETI Literature

There is a rapidly growing body of scientific literature on the subject. Apart from numerous articles in the journals, two thick volumes of 400 pages each have been put out in the past couple of years by the Science Publishers in Moscow. One volume was edited by Professor Samuil Kaplan of the Gorky Institute, the other by the late Dr. Boris Konstantinov, who directed the Physico-Technical Institute of the Soviet Academy.

Is the effort justified, you may wonder. In the words of the Byurakan conference, 'This problem may prove to be of profound significance for the future development of mankind. If extra-terrestrial civilisations are ever discovered, the effect on human scientific and technological capabilities will be immense, and the discovery can positively influence the whole future of man...'

---

* *The author is the well known Soviet Science writer who accompanied the late Yuri Gagarin to London in 1961. His article was supplied by the Novosti Press Agency.*

† *A recent Soviet expedition concluded that the object was a small comet. Ed.*

CETI Conference: Collected Papers

We understand from Professor Carl Sagan that the collected papers of the U.S./Soviet CETI Conference held in Soviet Armenia in 1971 will be published by M.I.T. later this year. – Ed.

STARDRIFT

A NAVIGATIONAL SYSTEM FOR RELATIVISTIC INTERSTELLAR FLIGHT

By A. T. Lawton

Introduction

In a recent paper Strong outlines some interesting problems concerned with travel at high relativistic speeds [1]. In this continuation of the 'series' the author outlines tentative solutions consistent with present knowledge but requiring the technical refinement presumed available when we consider interstellar travel. Relativistic phenomena can be turned to advantage in obtaining navigation fixes.

Navigation Problems

The navigator's problems may be outlined as:

(a) 'Where are we going'?
(b) 'Where should we be going'?
(c) 'What action do we take if (a) and (b) don't agree?'
(d) 'What is our speed'?

Differences between (a) and (b) determine course corrective direction, and when combined with (d) determine the direction, duration and total impulse of the course correction vectors.

As Strong points out, 'where are we going' is almost impossible to answer since relativistic aberration produces the 'starbow' described by Sänger, but we can also ask 'where have we been'? for it is perfectly legitimate to take fixes by looking backwards instead of forwards. Comparison of what is obtained with what is expected gives the information for corrective action.

In fact, the aberration which produces the 'starbow' is helpful, for the constellations will have opened right out with the departure star (or other reference star) at dead centre of a known position. For example, if we are heading towards *a Centaurus*, looking rearward we would expect to 'see' the Sun as an additional member to a very widely spaced 'W' *Cassiopia*. Indeed there would probably be a further collection of lower magnitude background stars some of which may provide further useful references.

How do we pinpoint and 'see' these references; how do we determine our true speed, and how do we correct our course?

Inertial Navigation

In addition to the standard system outlined by Strong, there is a further system of navigation which is based on sensing the slightest acceleration, integrating once to obtain velocity, and then integrating again to obtain the distance moved with elapsed time. This system holds true for all axes and is based entirely on its own frame of reference and not on what is happening to the outside world, and since it deals with inertial movement of the ship compared with a reference platform, it is termed 'inertial navigation'.

For the mathematically minded, the equations are—

$$\int_0^t g = u + g\ t \quad \text{and} \quad \iint_0^t g = s + u\,t + \tfrac{1}{2} g t^2 \qquad (1)$$

where 'g' is acceleration 'u' and 's' are integration constants which are the speed and elapsed distance respectively at the end of time 't'. See Fig. 1.

If the accelerations obtained in the 'xyz' axes are compared with a suitable reference set at the beginning of the voyage then theoretically we know where we are and how fast we are going. We can also feel a bit superior about it too, since the system is immune from radio interference, magnetic storms, bad fixes, and other 'nasties' which upset a commander's composure and digestion.

Because of this, the system is almost universally used for missiles (particularly ballistic missiles), nuclear submarines, low altitude (below radar) penetration military aircraft and other items wishing to go about their business without advertising whereabouts.

The system does suffer snags, the main ones of which are:

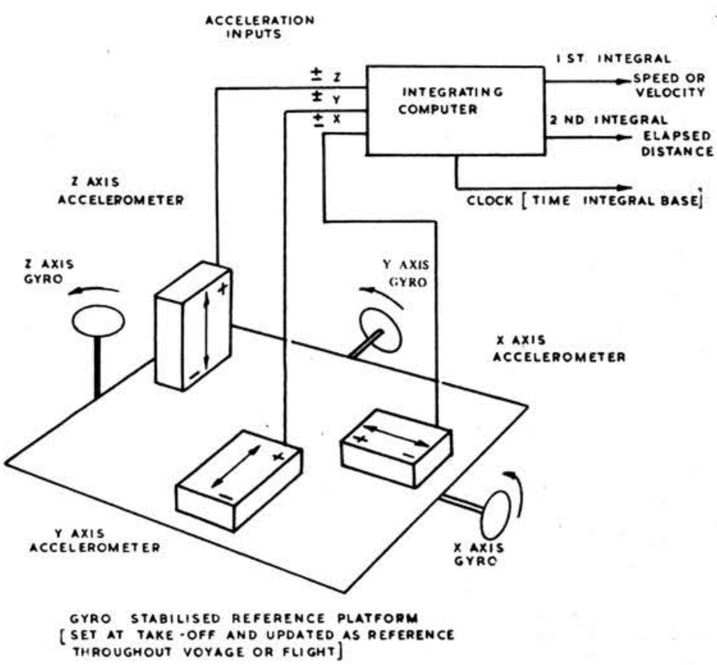
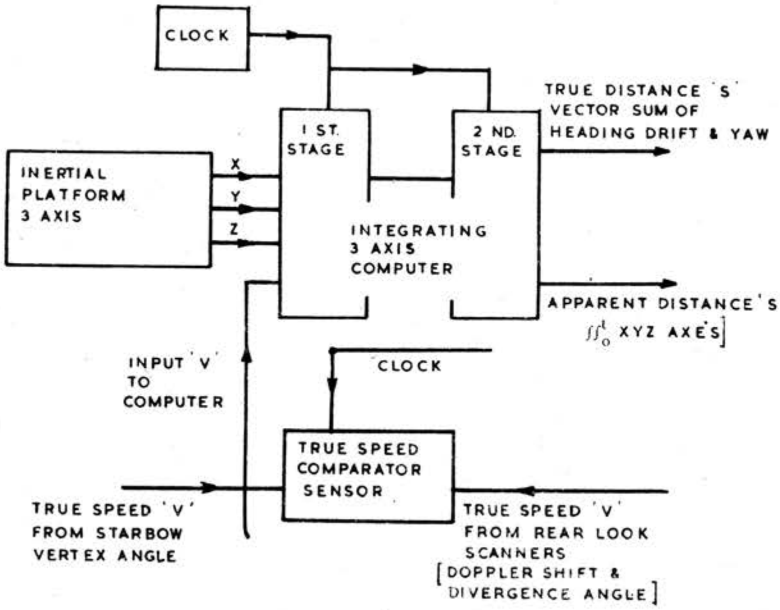


Fig. 1. Schematic of an Inertial Navigation System.

Fig. 2. Schematic of Interstellar Inertial System with true speed, true distance correction.



(a) The stable platform reference drifts (usually gyro bearing and gimbal friction).
(b) The integration is not perfect and integration errors are time cumulative.
(c) Time references for integration are liable to drift.
(d) The Earth rotates in 24 hours, and has to be compensated (so-called 'Schuler tuning').

All of the above have been reduced to acceptable levels for Earth bound use, and although security classified, some of the figures achieved are very accurate indeed.

Relativistic Inertial Navigation

In the Relativistic world, one expects Relativistic things and this is true of Inertial Navigation. The equations of (1) are Newtonian and must be modified as v approaches c the velocity of light. If we take the equation for the distance travelled as measured on the ship, it differs from the real distance travelled by the factor.

$$S'/S = (1 - v^2/c^2)^{1/2} \qquad (2)$$

and if we say v/c at the end of acceleration over distance S is:

$$v/c = \left[1 - \frac{1}{(1+g\,s/c)^2}\right]^{1/2} \qquad (3)$$

then substituting (3) for v/c in (2) we obtain:

$$S'/S = \frac{1}{(1+g\,s/c)^2} \qquad (4)$$

Now as Sänger points out, c^2/g (as on Earth) 9.81 m sec^{-2}, almost exactly equals a light year, and whereas S the true distance covered by acceleration with respect to time increases with time, the distance S$'$ measured within the vehicle of this distance S tends towards c^2/g, i.e., a light year no matter how long the real distance S may be.

To sum up, unless the crew can determine their real speed with respect to the outside world, they will always appear to cover a light year.

However, it is possible to determine true speed, and apply it as a correction to the Inertial Computer (as in Fig. 2) in order to obtain the true distance S, and Strong is incorrect when he says that determining the true speed tells the crew little else. On the contrary it is the key to Interstellar Navigation.

Referring to Equation (2) if we know S$'$(measured on board) measure v, the velocity of the ship with respect to c, then we can determine S, the true elapsed distance from the take off star. Since radiation is our only information contact with 'the outside world' we must use this radiation to determine our speed. Accurate methods of measuring speed are described later but they basically depend on the system outlined by Sänger. The subject is covered in detail by Sänger and Ackeret [2].

If we looked ahead say 500 years then it might seem feasible to have perfected such a system to work for the several years needed for an interstellar voyage. This *might* be the case, but even today's items usually carry a reference updating system, based on radar fixes, celestial navigation (star fixes), or plain 'By Jove, there's the target!' sighting.

It would be prudent to carry such a fixing system to 'tweak' our inertial computer now and again in order to sail a 'taut' ship and conserve valuable energy.

Relativistic Fixing

I said earlier that if we looked backwards we could 'see' our reference stars. Some will have shifted into the infra-red or microwave regions, some will still remain visible [3] but should be quite detectable and perhaps this requires some explanation. The Sun and similar stars are black body radiators with peak power radiation centered around 0.4μ to 0.6μ

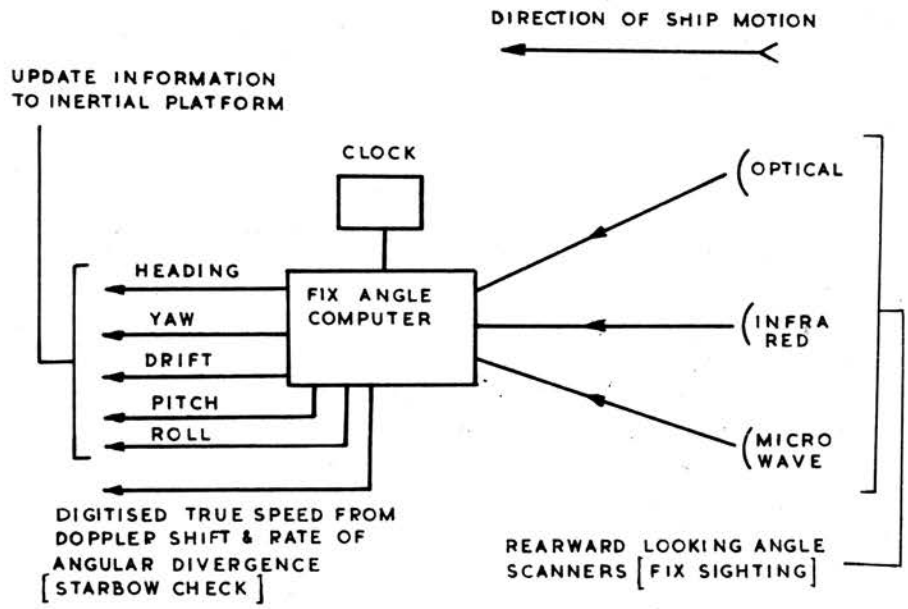


Fig. 3. Schematic Auto-fix Sensing Computer 'Star-Drift' Inertial System.

metres (4000 to 6000 Å). The radiation intensity therefore is down by a factor of 10^9 at infra-red wavelengths and approx. 10^{20} at microwave frequencies. Hence the only true star whose radio spectrum is detectable is the Sun. Other items emitting radio frequencies are not true black body radiators. Hence, even with the most sophisticated apparatus we cannot detect the radio spectrum of *α Centaurus,* although it is easily visible.

Such are the conditions from Earth as a frame of reference.

Now let us consider the Sun's spectrum from a vehicle travelling at relativistic speeds away from the Solar System. It is, of course, shifted towards the red end due to Doppler effects, *but the net energy output is unchanged,* and hence should be easily detectable.

The wavelength is red shifted by a factor of

$$\left(\frac{1 + v/c}{1 - v/c}\right)^{1/2} \quad \text{where} \quad \begin{array}{l} v = \text{ship velocity} \\ c = \text{velocity of light} \end{array}$$

Table 1 shows the expected peak radiation wavelengths for the Sun as observed from a ship travelling at various relativistic speeds.

Therefore, as seen from the ship, the measured separation angles of the constellations containing our Sun will

TABLE 1. Spectral Shift of Peak Radiation of the Sun at various Relativistic Speeds.

P S O L*	Peak Radiation	Remarks
0 (Earth)	0.5 μ metres = 5000 Å	Visible
90	5 μ metres = 5 microns	I R
97	16.67 μ metres = 16.67 microns	I R
99	50 μ metres = 50 microns	I R
99.9	500 μ metres = 0.5 m m	Microwave
99.99	5000 μ metres = 5 m m	Microwave
99.999	50000 μ metres = 50 m m	Microwave

* Percentage speed of light.

open out, and in extreme cases of $v/c \rightarrow 1$ the take off constellations will entirely fill the rearward field of view.

Any stars in the take off constellation which are double stars would be very useful for the small separation angles of the components in visible light, as seen from an Earth reference frame would open out into easily measureable angles at infra-red or microwave wavelengths. Since the reference stars are still minute points of radiation even allowing for relativistic dilation we should still be able to obtain accurate angular measurements.

The only star with any measureable angular diameter would be the Sun, and for an appreciable part of the voyage this could form a useful reference centre – although the resolution of a truly accurate centre to this diameter might be difficult (Fig. 3).

Obviously one chooses any reference fixes with care, and it is ironical to speculate that a native of a double or better still a triple star system starts off with a natural advantage for he would know the physical and real separation of the components with extreme accuracy (1 in 10^8). We can measure the real separation distances of the components of our own Solar System by means of radar and laser ranging techniques with similar or better accuracies.

Using the known separation distances and angles as a reference, he checks that these parameters change in accordance with relativistic prediction. If they do, he is on course, and he has a measure of his relativistic speed (PSOL number). If they do not check, then using alternative PSOL references (described later) he measures the deviations, computes the errors, and feeds the necessary corrections to the navigational computer which then controls the thrust direction/duration vector to re-establish our correct course.

We cannot use such a set up with our single star system for the outward journey to *α Centaurus,* but on the way home we would have a splendid reference system.

The distance between the 2 main components would be very accurately known having been measured as part of an overall survey of the system. If the distances from both main components to the third (*Proxima*) were also accurately

measured, then we have an automatic 3-point fix system. As the ship's speed increases so the angular separation (looking rearwards) will open out and the peak energies radiated will shift towards infra-red and then microwave frequencies as speed increases still further.

Let us assume that the course back to the Sun has been plotted and set into the computer.

The ship is started and normal fixes established in both forward and rearward directions until relativistic operation puts the forward look fix out of our accuracy requirements.

By then the apparent component separations will have shifted as shown in Table 2.

TABLE 2. Relativistic Separation Shifts of *α Centaurus* A and B

P S O L*	Main Component Separation A.U	
0	23.2	(mean)
90	232	"
99	2320	"
99.9	23200	"

The separation varies from 11.2 to 25.3 A.U in the course of a complete orbital cycle. This motion must be taken into account when course computing.

The present separation of *α Centauri C (Proxima)* is 0.1 Light Years or 94.5 x 10^3 A.U. This would shift with PSOL in a similar manner to the main components. The two components would also again show measurable angular diameters, which would provide references for the other points of radiation used also as navigation fixes.

How often would we take fixes? Looking so far ahead it is impossible to make any accurate forecasts except to say that as in all good navigation, the sooner the errors are detected and corrected, the overall course and time will be shortened and the fuel consumption lowered.

It is probable that daily check fixes would be made with monthly or even quarterly course corrections applied, but so much depends on the inherent accuracy of the inertial computer accelerometers, integrators and gyro stable platform. If one assumes steady development then it may be possible to integrate sufficiently accurately over a period of a year before course corrections are needed. Only time will tell.

Einstein or PSOL Meters and Measurement

Our speed '*v*' with respect to the speed of light is one of the most important items we must determine, for with it we can calculate true elapsed distances and courses with respect to our take off star. Later developments may be able to include the actual target star as a cross check. Three methods are available to us on board ship:

1. Measurement of external radiation Doppler shift.
2. Vertex angle measurement of the starbow.
3. Dispersion angle measurement of known constellations and star members.

Method 1. Doppler Shift Measurement

This already exists on board the interstellar ship, for the radiation sensors used for obtaining navigation fixes will automatically note the Doppler shift which occurs as the ship gains speed (Fig. 3). It should, therefore, be comparitively easy to select a distinctive absorption line at (say) the ultraviolet or violet end of the Sun's spectrum (say calcium K at 0.3934 micro metres or 3934 Å) and track the shift.

However, as the line shifts, it also broadens, and it may be difficult to keep a sufficiently accurate track, especially when switching through various types of sensor, i.e., visual, infrared and microwave. Since the microwave line occurs at the highest relativistic speeds where maximum accuracy is required it is doubtful if the shift can be tracked sufficiently accurately.

Vertex Angle of Starbow

Sänger gives a formula which connects the angle θ of a specific section of the starbow with the absolute velocity of the ship i.e.,

$$\cos\ \theta = \frac{1 - (1 - V^2/C^2)^{1/2}}{V/C} \qquad (1)$$

If we accurately determine $\cos\theta$ we accurately determine V.

But $\cos\theta$ can also be shown to be

$$\cos\ \theta = \frac{1 - (\lambda/\lambda o)\,(1 - V^2/C^2)^{1/2}}{V/C}$$

in which λo is a reference colour of yellow at 0.59 micrometers (5900 Å) and λ is the limit of optical visibility.

Thus as the speed increases the band of yellow light decreased in diameter and in the limit ($V/C \rightarrow 1$), $\theta \rightarrow 0$ i.e., the yellow band shrinks to a point round the target star (or wherever the ship is heading).

If we therefore set up a servo system using an 'on board' gas discharge tube stabilised to operate at 5900 Å as a reference, and arrange a prismatic or diffraction grating refractometer to select the matching band from the starbow, the correcting signal to the servo can provide a very accurate measure of θ and hence of V.

If a digitizing disc were connected to the servo, this would automatically provide a signal in the right form for computer infeed correction (Fig. 4).

It is likely that the system could read θ in microradians of arc, provided the gas discharge reference tube is stable and absolutely monochromatic. A voltage and temperature stabilised helium argon laser might well start as a basis.

Dispersion Angle Measurements

These as explained earlier only provide accurate speed measurements if the heading is correct.

The Complete Navigation System

The overall system would appear in schematic form as in Fig. 5, where all the elements described are shown. The only additional items are a memory bank, a data readout and system interface, and a master clock.

Memory Bank. This is the 'ship's log'. Initially all the launch star's co-ordinates and reference data are fed into it together with programming instructions for all system functions and voyage requirements. As each update takes place it is recorded and stored either for further reference during the voyage or for final readout at the destination. This memory could take various forms but it will almost certainly have 3 parts:

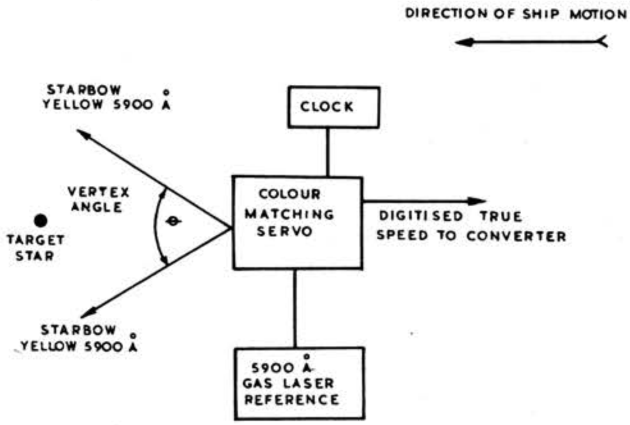


Fig. 4. 'Starbow' Vertex Angle Sensor and True Speed Indicator.

Fig. 5. 'Stardrift' Inertial Navigation System Schematic.

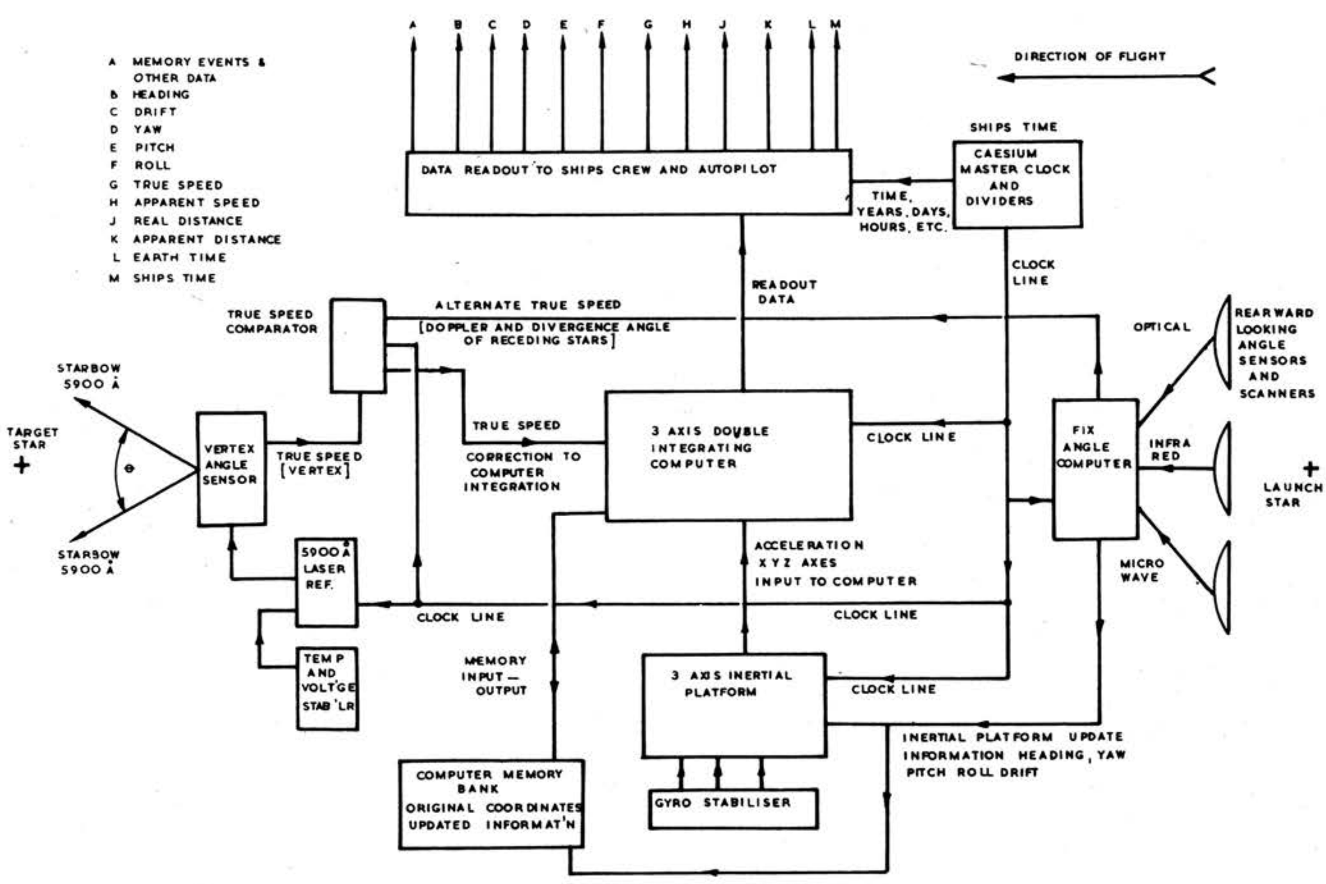
(a) A data storage bank for reference purposes.
(b) A programme bank for detailing particular sets of instructions and algorithms, as and when required.
(c) An active memory which receives (b) and acting on the instructions 'puts and takes' information from (a) to produce the required result.

Using today's more advanced 'hardware' technologies, (a) and (b) would be stored as holographic images, and (c) would be a silicon integrated circuit 'virtual storage' system. Both of these principles involve low power consumption, – an essential for the large sizes of memory likely to be used.

The author freely acknowledges that it is difficult to guess the memory and instruction bank size since it is likely that 'software' and High Level Languages in particular will have reached a stage of instruction which drastically reduces the storage needed.

Data Readout and Interface

This, as its name implies, reads out all computed data, and takes on board any information from other areas of the ship (total impulse available, mirror temperature of the 'photon motor', etc.).



Master Clock

This is the 'ship's clock', but it is much more than that, for upon its accuracy depends the whole success of the voyage. It reads out 'Earth Time', 'Ship Time' (the crew's time) and via the divider system, it 'clocks' the various sections of the computer and provides the time integral basis for the Inertial Platform. A present day caesium clock system (accuracy 1 in 10") would provide a good development basis.

The system is only shown in barest schematic outline, but it is unlikely that the overall system would be much larger than those used for present day submarine work. The degree of electronic sophistication would be much higher for all digital conversion switching, and read out, sensor switching, etc., would be entirely automatic.

Extensive use would be made of redundant circuitry and self repairing techniques as a means of maintaining reliability for, as much as the engines are the heart of the ship, this item would be a major part of its brain.

Relativistic time dilation would materially help the reliability situation for with a distance of 200 light years travelled at 99 P S O L means a real time on ship of 2 years and this is quite within the reliability expectations of today's equipments. Thus the majority of equipment for tomorrow's navigation is almost available from today's technology.

It is agreed that the 'Stardrift' system produces an apparent synthetic picture to the ship's passengers, but the use of synthetic pictures and music for passenger entertainment is a *sinqua non* of today's modern aircraft!

REFERENCES

1. Strong, J, *'Spaceflight'*, July 1971.
2. Sänger, E, *JBIS*, **7**, January-February 1962 (and associated listed references).
   Ackeret, J, *Interavia*, **11**, 1956, p.989.
   Ackeret, J, *JBIS*, **6**, 1946-1947, p.116.
3. Wiltshire, L, *'Spaceflight'*, December, 1971, 'Letters to the Editor'.

RECENT ADVANCES IN RADIO ASTRONOMY

By M. P. Damon*

Introduction

Any investigation of a scientific nature is generally concerned with the study of material objects and the effects of the interactions between themselves and the rest of the physical world. Any theory which is proposed along a given course of investigation must either fit into the ordered pattern of observed realities or be discarded. Thus the sole criterion for determining the success of a branch of science is to see how well and how accurately observations agree with theory.

In this respect, astronomy is no different from any other science, and here I would like to discuss some of the observational difficulties with which the Radio Astronomer has had to contend and how, to some extent, they have been overcome.

Observational Accuracy

The chief disadvantage of Radio Astronomy in comparison to Optical Astronomy has always been one of observational accuracy. Radio wavelengths in the high frequency band are of the order of 10^4 longer than that of visible radiation, so it is obvious that to obtain resolutions comparable to an optical telescope, one would need radio telescope apertures of several kilometres. For example, at a wavelength of 1m, the Jodrell Bank Radio Telescope (d = 82m) has a resolving power of ¾°, while for the Optical Telescope at Mount Palomar, whose mirror has a diameter of 5m, the beamwidth is about 0.02 arc sec. Thus the Radio Astronomer is very much worse off in this respect.

The primary objective of a Radio Telescope is to determine the positions and flux densities of celestial radio souces, and as such should possess sufficient resolving power and gain. There are several methods of overcoming, in varying degrees, the problems associated with high resolution mapping in Radio Astronomy. Firstly one can use, at the higher radio frequencies, precision parabolic reflecting dishes. The directional properties of a radio telescope are determined entirely by the aerial system used, and the only way to decrease the beamwidth is to increase the effective aperture. Thus in the case of a simple reflecting dish – or radiometer – the larger one can make the reflector, so the angular resolution will increase. However, parabolic aerials require a high level of engineering ability and much research into the dimensions of reflector surface, into the elastic properties of support structures, and into aperture shadowing by feed systems and spars, is necessary. So the limit to which one can increase the physical size of the reflector is set purely by the mechanical difficulties associated with supporting massive reflectors without suffering deformations brought about by the combinations of dead load, wind load and thermal unbalance.

When it became clear that a simple increase in the size of radio telescopes was not feasible, the next logical step in the direction of improving angular resolution was the adoption of Interferometric techniques in Radio Astronomy. It may be recalled that Michelson was the first to apply interference principles to Optical Astronomy, and his system can be seen in Fig. 1. The image for a point object produced by an optical system is not a point image but a Fraunhofer diffraction pattern, and one can determine the intensity distribution across the focal plane of the instrument from the contribution from each slit. If $a \ll b$, then it is found that the intensity distribution approximates to a cosine^2 distribution, and the Resolving Power as defined by Rayleigh's Criterion is given by $RP=\lambda/2(a + b)$, and is the minimum detectable angular seperation of the two sources. All this means is that the Resolving Power of a single rectangular aperture can be doubled by the use of two single slits situated at the edges

* *Technical Director, Cosmic Electronics.*

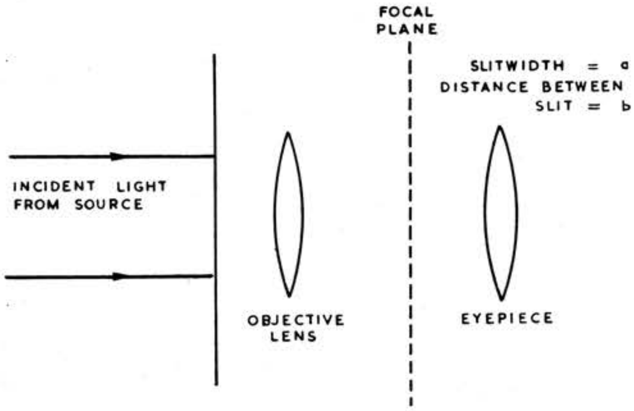


Fig. 1. Michelson's Stellar Interferometer.

of the larger slit.

The Radio analogue of the Optical Interferometer can also be simply shown in Fig. 2, and the same arguments apply. The resolution of the simple radio telescope can be increased by using two aerials connected to a receiver and separated by a distance 'd'. As the baseline d is increased so the resolution of the instrument increases, and the receiver output will follow a cosine^2 distribution. The dashed line shows the output obtained with a single aerial, and the polar diagram of the two combined aerials is shown in Fig. 3 as a multilobed fan. As with the simple radiometer, however, this system also possesses its disadvantages, and they are:

(1) Differences and variations of amplifier amplitude and phase responses;
(2) Sensitivity to large background energy variations; and
(3) Atmospheric inhomogeneities.

Since the application of interferometry to Radio Astronomy, it has been continually developed and expanded and nowadays very sophisticated techniques exist, involving phase switching of the interferometer to overcome the phase and stability problems, radio interferometry using radio relay links to achieve base lines of several kilometres and more are quite commonplace.

The third method of accurate position determination is that of lunar occulation – that is by timing the instant at which the source disappears behind the edge of the Moon and the instant at which it appears. This method has been used by Hazard and others, first in Australia and more recently at the Arecibo Radio Telescope in Puerto Rico. For sources which exhibit low angular spread it has proved to be valuable, but difficulty arises when sources of wider spread are investigated, as large numbers of occulations are required to give accurate and reliable results. It must be mentioned that occulations will only occur, anyway, for sources lying near the ecliptic.

Aperture Synthesis

With the advent of large commercial computers, it has become possible to simulate the performance of large aerial arrays. This method, known as aperture synthesis, was first described by Ryle and Hewish. Briefly the method entails the use of two or more small aerials which can be moved to occupy various positions within a much larger 'synthetic aerial aperture'. The outputs of these two aerials are fed to a correlation receiver, and any change in the separation or azimuth angle of one or both of the aerials will alter the phase and amplitude of the resulting electrical signal in a manner which is wholly dependent on the structure of the radio source. By moving the two aerials over the synthetic aerial aperture and by combining the results of amplitude and phase with a computer, it is possible to build up a radio picture of the source, with the angular resolution of the larger synthetic aerial. To avoid the necessity of moving the dishes in two co-ordinates to cover the whole plane, a simple method often used is to mount the aerials on an East-West baseline, and if the observations are carried out over 12 hr. intervals, then the rotation of the Earth itself provides the synthesis of an aperture parallel to the equatorial plane. By using different aerial separations, full aperture synthesis may therefore be obtained.

The 5 km Radio Telescope

This work on aperture synthesis culminated a few months ago with the opening, by the President of the Royal Society, Sir Alan Hodgkin, of a new 5 km Radio Telescope at Cambridge, utilizing the aperture synthesis principle. With this instrument the Radio Astronomer now has at his disposal a means of mapping radio sources with a resolution that was previously met only by optical telescopes – of the order of 1 arc sec. The chief purpose of this new instrument is to reveal fine structure details of sources that were observable using previous instruments, but which had insufficient resolving power to show processes by which successful theoretical models could be constructed. Typical sources under investigation will be the double structure of some radio galaxies, and the interaction of expanding supernova shells and the interstellar medium.

Before work was started on the project, however, one important system parameter that had to be determined was the upper limit to the synthesis aperture, for at first sight it may seem that one can increase the aperture indefinitely to

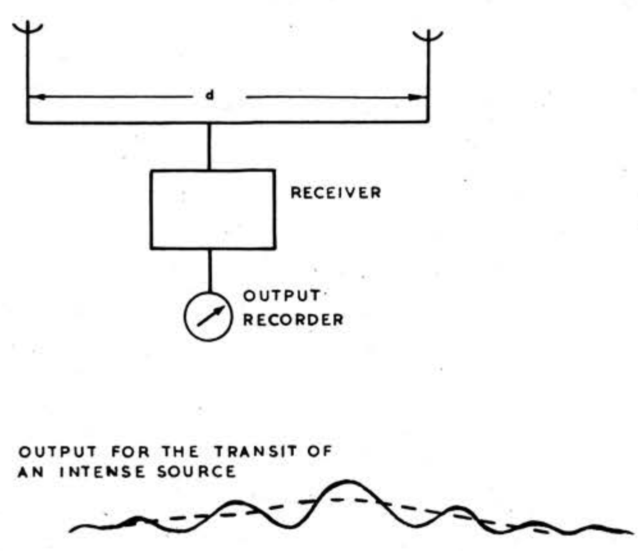


Fig. 2. Radio Interferometer.

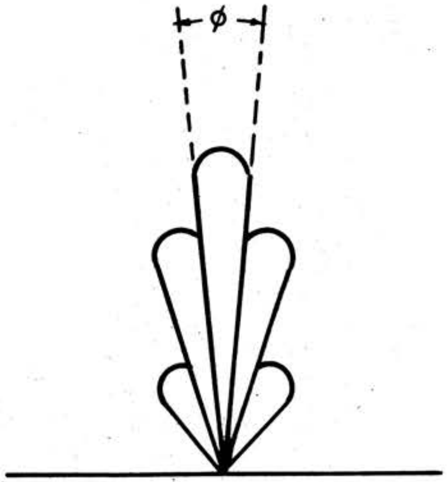


Fig. 3. Aerial polar diagram for a simple interferometer.
ϕ = lobe spacing = $\frac{57\lambda}{d}$

obtain any required angular resolution.

The limitations to the resolving power of such an instrument stem from the same sources that restrict the Resolving Power of any Earthbound telescope – whether Optical or Radio – and this is the alteration of phase across an incident wavefront produced by random refractions in atmospheric irregularities. At lower frequencies, these irregularities are caused by inhomogeneities in the ionosphere, while higher frequency variations are attributed to turbulence in the troposphere.

The previously constructed aperture synthesis instrument at Cambridge, the One Mile Telescope, was thus used in a research programme to first of all determine the upper limit to aperture size and then to determine the extent to which these irregularities were dependent on weather conditions. These studies showed that the disturbances would indeed prevent the use of very large synthesis arrays and that spurious refraction effects on the ray paths meant that aperture sizes would be limited to 10 km, with instruments operating at wavelengths between 3 and 10 cm. The results also showed that statistically, for 50% of observation time, angular resolutions would exceed 1 arc sec.

The new 5 km system uses eight 13 m dishes arranged on an East-West baseline 4,6 km in length. The electrical connections between the element dishes are so arranged as to provide 16 separate pairs, thus enabling a high mapping rate to be achieved. The dishes themselves were provided by the Marconi Company, and were slightly modified satellite tracking aerials.

Much of the data reduction on this instrument is done in real time by an on-line computer. This enables the results of an observation run to be ready for inspection shortly after finishing the run, instead of having to wait several days as with the previous synthesis instruments at Cambridge which employ paper tape acquisition.

So now the Radio Astronomer has at his disposal an instrument that can match the performance of optical telescopes in the ability to resolve fine structure of celestial objects. Furthermore it will also enable precise position determination to be made of radio sources, leading to the creation of new reference radio sources.

Obviously to achieve this kind of observational accuracy, spacings of the aerial elements and lengths of electrical feed and distribution paths have had to be carefully controlled, the aerial foundations being positioned to an accuracy of 1 mm as are the coaxial cables connecting the dishes to the correlation receiver.

The new instrument is not intended to be used for Theoretical Cosmology or for the widening of the visible Cosmic horizon. Existing instruments can already look back in time to the formation of the Galaxies, whereas these same instruments are quite incapable of resolving fine structure of quasars or radio galaxies. Thus the 5 km telescope will concentrate on closer work, for example on supernova remnants in which a very extensive plasma reacts with an ambient medium. Other important areas to be studied will be the H 11 regions – parts of the Milky Way which contain ionised hydrogen. These are important because, being rich in organic molecules, they appear to be the sites of new star formation.

It is hoped that the new Aperture Synthesis instrument will uncover new secrets of the Universe, leading the way to both the discovery of new phenomena and the conclusive proving of old theories; but like everything in which Mother Nature participates, only time will tell.

OUR "EQUIPMENT FUND" MID-YEAR APPEAL

Dear Member,

Eighteen months ago the B.I.S. Council set up the 'Equipment Fund' Appeal.

Donations received to date total £1800, and, as a result of this, we now have two composing machines at work preparing our publications.

The steps already taken have helped to maintain and improve services to members, but much remains to be done. Further items of equipment are needed, including e.g., a photocopier of moderate size.

Donations are therefore being sought at this time of the year, so that plans may proceed without delay. Will you please help us?

Cheques, etc., should be made payable to the B.I.S.

Please write your name and address on the reverse side together with the words 'Equipment Fund' (no accompanying letter is then necessary).

All contributions will be most gratefully received and acknowledged.

Please give your support.

Yours sincerely,

G. V. GROVES.

PRESIDENT.

EVOLUTION OF THE SPACE SHUTTLE

NORTH AMERICAN ROCKWELL – PART 2

By David Baker

Part 1 of this article, which appeared in the June issue of *Spaceflight*, reviewed the pre-Phase B approach to Space Shuttle design. Part 2 looks at the definitive approach to the fully re-usable vehicle. Part 3, to appear shortly, will review the changes that have since resulted in external tanks for the orbiter and replacement of the manned flyback booster with a ballistic boost arrangement.

Phase B Studies

The Space Division of North American Rockwell began a funded definition study of the Shuttle early in July 1970, using as a baseline the high and low-cross-range variants of the orbiter and the General Dynamics B8C booster. Full details of these vehicles appeared in Part 1.

The work statement for the NASA Phase B studies anticipated a configuration selection by the end of September and a 90-day review determined that the high-cross range orbiter would be selected for definition and a preliminary design to the subsystems level. The orbiter, known as the 134C, was essentially the same as the model that had won for NR the coveted prize of Phase B contractor several months earlier. However, changes had come to the booster, now designated the B8J, and the vee-tail configuration had been replaced by a vertical rudder/stabiliser assembly, and a horizontal, all-flying tail. Some 714 hours of wind tunnel research at the Langley Center had displayed improved pitch damping and yaw control from the more conventional arrangement.

Six months after commencing definition work NR and its booster contractor General Dynamics reviewed with NASA the configuration requirements and sizing ground rules that would dominate the second half of Phase B. It was determined that the selected configuration must accelerate a 25,000 lb. payload into a 270 nm orbit at 55° inclination, provide a 1500 ft/sec. on-orbit manoeuvre capability and a fly-back using air-breathing engines. With a thrust/weight ratio of 1.3 the boost phase would be constrained to 3g.

With a further 260 hr. in the wind tunnel General Dynamics substituted a delta wing for the high aspect ratio design of the B8J. The vertical stabiliser remained unchanged and pitch attenuation was assured by the addition of a canard mid-way between the leading edge fillet and the nose. This new configuration was to be known as the B9T, and with it the NR-161B orbiter, itself the product of 200 hr. wind tunnel studies. Gone were the outboard stabilisers and twin rudder assemblies and instead the slightly ogive wing terminated in a knife-hatch trailing edge set 95° to the elevon plane. The vertical tail incorporated a split rudder with air brake capability and the flat underbody was faired across to a circular nose section just forward of the crew compartment. Two 620,000 lb. thrust engines were positioned side by side aft of the cargo bay and above the wing carry-through box. Twelve 540,000 lb. thrust engines, using similar propellents, powered the booster.

During the first quarter of 1971 additional inputs to the ground rules demanded a substantial upgrading of the capabilities. In addition to the reference mission of 25,000 lb. to a 270 nm, 55° orbit, the orbiter would now have to demonstrate a 65,000 lb. lift capability to 100 nm at 28°, and 40,000 lb. to polar orbit with a 90°, 1100 nm, due east turn on entry. Only the initial mission envelope would require air breathing engines.

The final Phase B proposal from North American Rockwell was the 161C orbiter and the B9U booster. Some 931 hours in the wind tunnel had been required to finally turn the 161B/B9T into these hybrid variants, the subject of the following analysis.

The NR 161C Orbiter

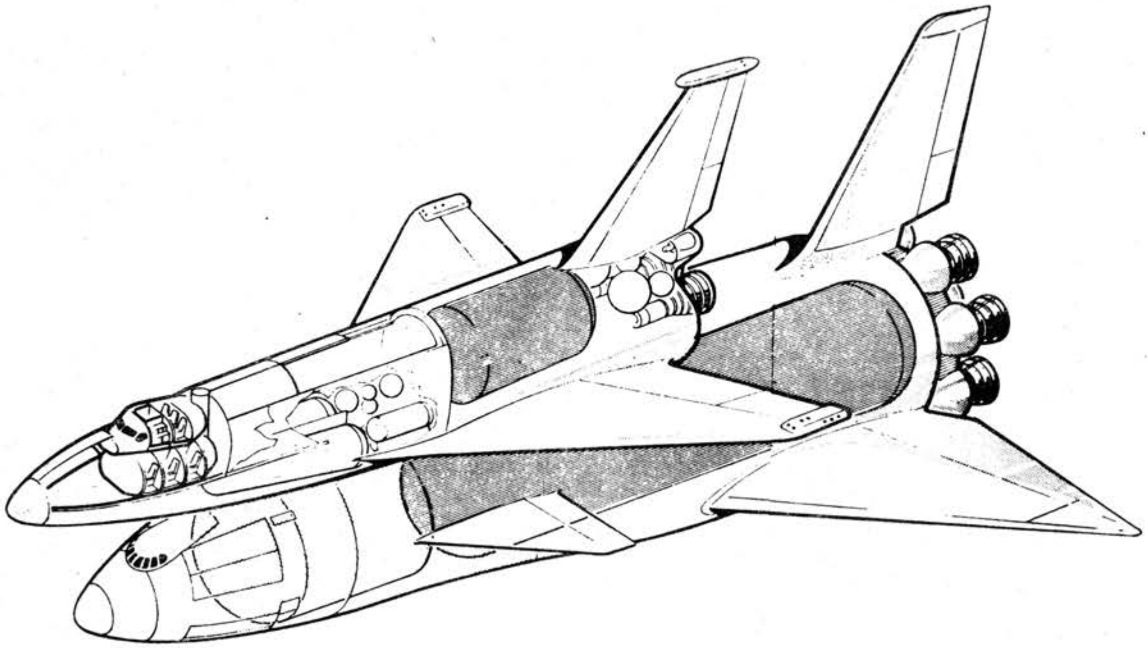
Primarily fabricated from titanium the definitive Phase B orbiter was substantially larger than the high-cross range design of mid-1970. With a length of 210 ft, a wingspan of 124 ft. and a tail height of 61 ft. the orbiter can be separated into two body areas with nose and tail sections added. The forward section includes the crew compartment, cargo bay access tunnel, and the single liquid hydrogen tank constricting the dimensions of the nose and lying along the full diameter of the forward section.

The integral LH_2 tank is stiffened and fabricated from 2219-T87 alloy, with titanium stand-off frames and internal thermal insulation. The cabin is similarly fabricated and adopts the next best principle to a floating compartment with an expansion link mounted to the rear skirt assembly. Of skin and stringer construction, utilising titanium alloys, the forward and rear skirts support the nose and aft fuselage assemblies respectively. The ovoid rear fuselage is basically a shell of skin-stringer-frame construction in titanium and supported by an internal truss assembly. The dual floating LOX tanks are of semi-monocoque design from 2219-T87 aluminium with orbital manoeuvring propellent tanks of similar construction. The 60 ft. long cargo bay is covered with titanium, skin-stringer frame doors, supporting radiators for the environmental control system. Attached to the rear of the aft fuselage is the thrust structure, serving as a stress mounting for the two H_2/LOX main propulsion engines, the vertical tail and rudder assembly, plumbing for the propellent delivery, and launch tie-down for the engine-on condition during ascent. A base heat shield of Inconel 718 provides thermal adsorption, with a truss-supported aluminium frame supporting the outer shell on stringers and titanium frames. The nose section adopts the skin-stringer construction method and is stressed to support the nose landing gear with an aerodynamic shell presenting an optimised flow for the wetted area of the fuselage. The wing incorporated sine wave spars with stiffened ribs supporting a rigidised skin and incorporated a lower fuselage carry-through box that transmitted loads in the absence of structural members. A leading edge fillet was built up from false spars, and sub ribs.

Thermal Protection (Orbiter)

Thermal protection was provided through four basic external coverings: titanium, for temperatures up to 700°F, reusable surface insulation (RSI), for temperatures up to 1800°F, and reinforced carbon-carbon (RCC), for those limited areas subject to temperatures in excess of 1750°F and up to 2,650°F. The entire underbody, nose section sidewalls, wing undersurface, and upper leading edges were covered with REI, with RCC adopted for the undersurface of the extreme nose and wing leading edges. The upper section of the fuselage and upper rear planes and control surfaces were covered with titanium, Inconel 718 providing protection for the fin leading edge and rudder, exposed to a maximum 1950°F.

The basic philosophy behind the design emphasied a desire to achieve a low cost structure with emphasis on



Final Phase B definition study of fully re-usable Space Shuttle. *North American Rockwell/British Aircraft Corporat*

conventional assembly methods, achieving liberal tolerance and the minimum reliance on exotic materials. Tooling costs would be an important factor and efforts were made where-ever possible to achieve a commonality of structure.

Aerodynamically the 60° swept delta, married to a soft chine body of moderate fineness ratio, provided good subsonic characteristics with an improved L/D in the hypersonic and transonic region. The blended wing/fuselage interface contributed to the effective damping of shock-wave scrubbing and the improved tail area reduced the supersonic drag, characteristic of the 134C. The adoption of a vertical tail provided good C_L stability at low α and minimised control reversal, coupling, and yaw at transition. Full span elevons provided pitch and roll control for all phases from entry to landing but yaw control was aerodynamic from Mach 7 only, the auxiliary propulsion system being used for yaw control down to 100,000 ft.

The L/D ratio of 7.5 at 9° α in subsonic flight enhance the flare characteristics and a C_L entry of 0.6 at 20° reflects the considerable improvements made in the aerodynamics of the design from the 134C. A static stability corridor of 37° α at Mach numbers from 10 to 24 is slightly more constraining than that effected by the 134C but entry at 55° followed by a pitch-down to 22° at Mach 18 permits conformity all the way to Mach 8 where transition down to a 9° pitch for Mach 4 satisfactorily eludes the longitudinal instability region, totally absent at lower Mach numbers.

Propulsion Systems (Orbiter)

The propulsion systems would be required to carry the orbiter to orbit from a platform of 48 miles and 8,500 ft/sec, manoeuvre the vehicle in space, and maintain attitudes, perform translation, and retrofire for de-orbit. To achieve orbital insertion the 161C would use two 632,000 lb. vac-thrust engines fed from the single forward LH_2 tank and two cylindrical LOX tanks. The total propellent load for the main propulsion system was 565,940 lb, with an additional 25,441 lb. provided by the engines, heat shield, propellent feed system, helium pressure bottles and recirculation system. Fill ports were provided aft of the heat shield.

The auxiliary, or orbital manoeuvring system would provide delta velta increments for phasing, orbital changes, and de-orbit operations. Three 10,000 lb. thrust LH_2/LOX engines were situated in a flaired closeout above the two main propulsion engines and beneath the rudder area. About 30,100 lb. of propellent would be carried for a total ΔV of more than 2,000 ft/sec.

The attitude control system consisted of 29 LH_2/LOX thrusters, of 2,100 lb. force each, situated in clusters on the nose, upper fuselage, lower fuselage, upper rear fuselage and tail. Small translation manoeuvres could be made and the propellent feed was coupled with that of the orbital manoeuvre system.

For ferry purposes and post-entry powered flight four JP turbojects were provided as an option. Requiring more than 18,200 lb. of what would normally be payload the air-breathing engine system was the subject of much discussion, prompting a test programme with the HL-10 to determine the handling characteristics of unpowered flares and landings.

Electrical power was provided by three fuel cells situated directly aft of the crew compartment and fed from LH_2 and LOX tanks directly beneath the auxiliary propulsion systems propellent tanks. Four APU modules, fed from inlets on the tail area, provide back-up facilities in the event the fuel cells suffer a triple failure. The hydraulics were slaved to the APUs for elevon, rudder, drag brake (split rudder), main landing and nose gear, and cargo bay deployment, with engine gimbal and valve controls on a separate redundant circuit. Each APU controlled a different system with failure redundancy built in on the critical subsystems. The undercarriage did possess a free-fall feature for quadruple in this area, however.

Environmental Control (Orbiter)

Environmental control of the pressurised areas demands a mix-gas Earth-atmosphere, system and was divided into: (a) atmospheric and water management, (b) contamination and thermal control, and (c) waste management. Oxygen and nitrogen vessels, pressurised to 900 and 3000 p.s.i. respectively, were to supply gas through regulators restricting the pressure to 120 p.s.i. to cabin atmosphere control valves with a partial pressure sensor on the 0_2. Excess water from the fuel cells is stored in a portable tank for delivery on demand to the food management system, with residual quantities stored in the waste water tank for urinal and water management use.

Humidity control and CO_2 removal is contained within the water loop with fuel cell and hydraulic heat exchangers serviced by freon and fed to radiators on the cargo bay doors and sublimators in the aft fuselage.

Waste management includes overboard dumping from the waste collector and urine storage tank via a separator.

The flight deck provided habitation for two crew members and two payload specialists. Provisions were incorporated for food and water management stations, sleep areas, and access to the cargo bay via an airlock and crew transfer tunnel. Several missions would require shuttle-to-shuttle docking and a compatible docking assembly was attached to the airlock immediately to the rear of the crew area.

With a flight weight of 859,000 lb. the 161C was the final definitive design of a mandate fully oriented toward maximum reusability and minimum launch cost. However, non-recurring DDT & E costs would be $4.9 billion (U.S.) with a peak annual figure of $1.1 billion in fiscal year 1976.

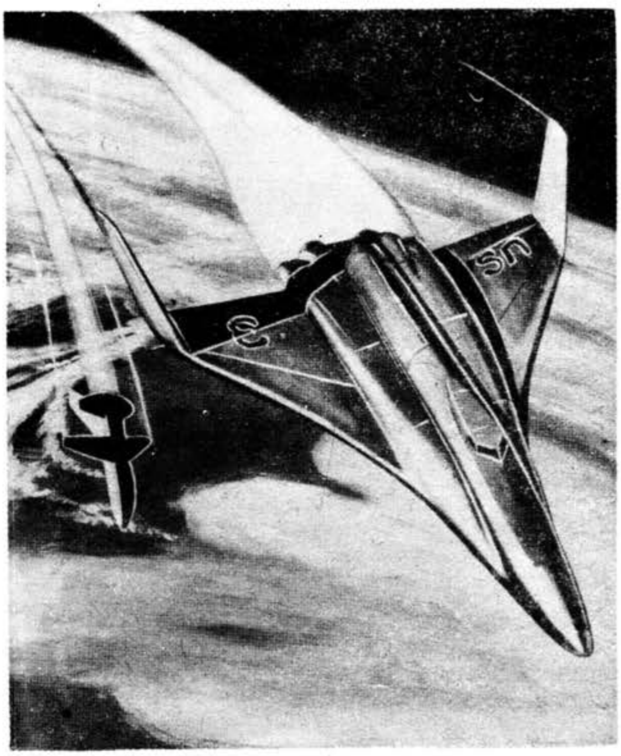
The GD B-9U Booster

The B-9U booster concept had its origin in the Phase B proposal submitted to NASA in early 1970 and stems directly from the B-8C, described in Part 1. A major configuration change was made in the last 2 months of 1970 from a forward straight wing/horizontal tail reunion, the B-85, to the aft-delta wing/forward canard version, the B-9T. The final refinements were made in February 1971 and labelled the definitive configuration the B-9U.

The B-9U was a low-delta wing vehicle with a single vertical tail and a small canard surface mounted forward above the fuselage centre-line. The main function of the booster, reflected heavily in the visual profile, was to accelerate the orbiter to a velocity of more than 10,000 ft/sec. at an altitude of 242,000 ft. More than 75% of the gross weight would be propellent and the total vehicle can but be defined as a very sophisticated, aerodynamic, manned, recoverable launch vehicle.

With a length of 269 ft, a wingspan of 143.5 ft, and a height to the tip of the tail of 102 ft, the B-9U would gross 4,188,000 pound weight and contain 3,382,000 pound of propellents.

The fuselage can be sub-divided into 5 structural elements: the nose and crew module, an integral LOX tank, intertank structure, integral LH_2 tank, and a thrust structure taking tail loads and carrying the 12 main engines at the rear. The forward section, or crew module, was to be fabricated from 2024 aluminium supported by Rene 41 frames, with a secondary structure accommodating thermal protection. The forward dual-wheel nose landing gear would retract forward into the area beneath the flight deck. Windows of high temperature resistant glass were provided for crew visibility.



High cross-range orbiter (Model NAR 134C) proceeds into orbit as manned fly-back booster drops away. The orbiter was designed to carry men and 50,000 lb. of cargo to space stations in the late 1970's.

North American Rockwell

Aft of the forward section lies the integral LOX tank, a cylindrical container 33 ft. in diameter and 56 ft. long with ellipsoidal end bulkheads. The tank is a welded assembly of 2219T87 aluminium with stabilising frames set 77 in. apart and integral stringers milled from aluminium alloy plates.

Aluminium 2024 frames supported the alloy skin, flattened at the top for orbiter interface. The LOX tank is similar to that incorporated in the S-1C stage of the Saturn V.

An intertank adapter separated the propellent tanks and was a skin-stringer construction fabricated from 2024 aluminium. The forward orbiter attachment struts were secured to the upper section and the canard pivot mechanism to either side of the fuselage at this location.

The integral LH_2 tank, 33 ft. in diameter and 148 ft. long, is the principal item contained within the fuselage and is responsible not only for carrying propellent but also for supporting the aft orbiter attachment point and wing. Closely spaced 2024 aluminium stabilising frames support the stringers and accommodate the compressive bending loads. A polyphenylene oxidefoam, coated on the interior walls of the tank, would provide cryogenic insulation.

Twelve high pressure rocket engines were mounted to the rear of the fuselage in the section known as the thrust structure. A titanium truss assembly was chosen, with a Rene 41 carbon coated base plate doubling as a thermal shield. The skin in this area was also integrally stiffened titanium.

The vertical tail assembly is a 3-spar integrally stiffened structure featuring skin/stringer construction with the spars

Table 1. Weight Summary.

TOTAL CONFIGURATION:	
Lift-off	5,047,000 million lb
ORBITER:	
Gross	859,000 lb
Main Propulsion Engines	·17,620 lb
Heat Shield	680 lb
Propellent System	7,141 lb
Useable Propellent	559,795 lb
Residual Propellent	6,145 lb
Auxiliary Propulsion System (Dry)	13,194 lb
Orbital Manoeuvre Propellent	30,136 lb
Attitude Control Propellent	4,566 lb
Total Aux. System	49,600 lb
ABES Dry Weight	14,542 lb
Fuel	3,528 lb
ABES Launch Weight	18,266 lb
Power Generation Dry Weight	3,894 lb
APU	1,231 lb
Fuel Cells	872 lb
PGS Launch Weight	6,293 lb
Hydraulic System	7,610 lb
BOOSTER:	
Gross	4,188,000 lb
Propellent (Ascent)	3,382,000 lb
Propellent (Cruise)	144,000 lb
Landing Weight	658,000 lb

and webs of corrugated construction. Only the leading edge is not fabricated from titanium, high thermal loads in that area requiring Inconel 718.

The fail safe, multi-spar, multi-rib wing structure utilises open corrugation panels on the upper surface and a thermally protected lower surface. Formers, ribs, spars, and skins are in titanium with 3-piece elevons to port and starboard of the fuselage. Detachable tips give a clipped appearance, distinguishing the B-9U from the earlier B-9T.

The all-flying forward canards are made up from a conventional multi-spar, multi-rib configuration with corrugated titanium skins supported on a welded, shear web structure. Lateral pivot tubes are hydraulically actuated from a truss support assembly.

Thermal protection of the fuselage was afforded by a metallic radiative system protecting the primary load carrying structure to a temperature compatible with aluminium materials. Hot gases surrounding the vehicle are transmitted to the corrugated outer panel by conduction and thence by radiation to the atmosphere. Carbon-carbon material was to be used for areas exposed to temperatures approaching 3,200°F, with coated columbium, H8188, Rene 41 and Inconel 718 protecting less severely exposed areas.

Overall, the 53° delta wing provided good stall characteristics and stability across the entire flight regime with adequate control effectiveness provided by the vertical tail, an improvement over the early B-8C. Entry into the Earth's atmosphere would be made at 60° α at Mach 8, rotation to 30° at Mach 6.5 and progressively down to 2° from Mach 2.5 to 1.0. The stability corridor provided at 25° pitch up limit at entry.

Propulsion System (Booster)

The main propulsion section consisted of twelve 550,000 lb. thrust, high pressure, LOX-LH_2 engines mounted on the aft thrust structure and producing a combined lift-off thrust of 6.6 million pounds. LOX, taken from the forward tank is transported through four 22-in. diameter supply ducts underneath the hydrogen tank to the 12 13-in. lines which connect to each engine inlet. LH_2 is fed from the rear of the single tank through 12, short, 13-in. pipes to each engine. LO_2 recirculation lines interconnect the supply lines and provide an anti-geysering path.

The booster was never intended to enter orbit and therefore the only other reaction propulsion required was the auxiliary system for altitude control down to final transition following entry. Thirty, 2,100 lb. thrust LOX and LH_2 engines were positioned at various locations for roll, pitch and yaw control, fed from tanks located in the intertank structure. Sixteen yaw motors were housed in two modules, on each side of the nose section for yaw control, with four pitch motors located on top of the crew station decking. Ten motors, in two packages on each upper wing section adjacent to the elevons, provided coupled pitch and uncoupled roll control. Fill ports were provided in the aft thrust structure.

The air-breathing engine system, ABES, consisted of 12 low-bypass ratio derivatives of the JTF22A-2 engine with a single fuel tank holding 109,000 lb. of JP-5. This would provide a 400 mile flyback capability and a substantial ferry range. A secondary fuel tank, located in the extreme nose beneath the flight deck, would hold 35,000 lb. of fuel for transfer to the main tank during cruise. The engines themselves were grouped into three sections of four each and mounted within the centre fuselage and each wing, facing rearward. Deployment was effected by rotating the unit through 180° from a forward pivot point, bringing the engines into a forward facing configuration beneath the undersurfaces.

Hydraulic control of elevons, canard, rudder, ABES deployment, landing gear actuation, brakes and engine gimballing is provided by four independent circuits fed from eight APUs. The fluid used would be MIL-H-5606 into a 240 g.p.m. line system with temperature constraints of -20° to + 275°F.

Environmental Control (Booster)

Environmental control and life support equipment provides thermal and pressure environment control for the vhicle and its crew. Before launch GSE supplies circulate conditioned air to the flight deck, crew station, and rear fuselage, with water circulation also maintained during this period. Circulation fans provide air for the ascent, with 2 air-cycle refrigeration packages ensuring environmental control during flyback. The air conditioning system is fed from four ABES units, cooled in the refrigeration package and distributed to heat exchangers, compressors, turbines and a water separator. GN_2 is used to prevent ice-build up in the propellent tanks and also to purge the engines.

The flight deck for the B-9U was a two-place, pressurised volume containing flight controls and displays, avionics, and an ingress/egress unit whereby the crew would board the vehicle when in the vertical position.

The gross launch weight of the B-9U was some 4,188,000 pounds with a landing weight of 658,000 lb. It represented

what would be seen in retrospect as a major factor in the conceptual changes that kept the Shuttle design on the move for nearly a year.

The combined system would be too large and costly for support, necessitating a major investment effort procurement, increasing the programme costs, yet achieving the lowest launch cost. The NR-161C/GDB-9U would have displayed a vehicle length of 290 ft, a maximum span of nearly 144 ft. and a mated height of more than 100 ft, weighing 5,047,000 lb. at lift-off. The integrated flight profile anticipated staging at 240,000 ft, 110 n.m. downrange and at a velocity of 10,800 ft/sec. (M=11.5). Max. - q would occur at 40,000 ft, at Mach 1.34, and create 506 PSF. During ascent pitch and yaw would be controlled by TVC systems and roll effected by aero-system trim.

Costs and Schedules

The Phase C/D master schedule proposed by NR anticipated an ATP in the first quarter of 1972, preliminary design reviews in the first and second quarters of 1973, a critical review in the second quarter of 1975, and a horizontal flight one year later with orbital flight achieved in the second quarter of 1978. Fabrication would have begun in late 1973 with all five orbiters and four boosters flying by 1980.

The overall D.D.T & E costs at Phase B go-ahead were estimated at about $10.12 billion (U.S.), reducing to $9.12 billion by the end of 1970. The Williamsburg Conference of early 1971 brought new requirements to the Shuttle, upgrading the scale of the vehicle and setting the final Phase B closeout figure at $9.24 billion. Total cumulative costs to fiscal year 1979, the conclusion of development and the demonstration of an operational capability, would be $8.44 billion, with peak annual funding in FY 1976 of $1.92 billion. Thereafter, operations would require an investment of between 50 and 100 million dollars.

Orbiter fabrication and development would require a total investment of $4.89 billion with a peak annual figure of $1.07 billion in FY 1976.

Booster development would absorb $3.53 billion over eight years with a peak of $0.85 billion in FY 1976.

The NR-161C/B-9U combination represented the definitive, most sophisticated, and yet most functional design since NR begun their studies a year before. Its major failing lay in the high costs such a concept would incur and at this time NASA had a mandate to keep the total cost over six years to $4.5 billion or so. It seemed an impossible situation. The orbiter alone would cost more than that!

Soon the industry would be wrestling with its own problems; compromises driven in by Washington and destined to force apart for all time the manned booster and the manned orbiter. From mid-1971 the entire approach was to change. Economics of annual funding rates would play a key role in designing the final configuration.

[To be concluded.

A CHRONOLOGY OF THE SPACE SHUTTLE – 2

By David Baker

[Continued from June issue, page 214.

1972

Jan 13 — MSFC issue 2 month contracts to Aerojet General, Lockheed, Thiokol and United Technology Centre for analysis of potential application of 120 in. and 156 in. solid propellent boosters to the Shuttle. Each contract is valued at $150,000.

Jan 25 — MSC issues a 16 month contract to General Electric ($407,630) for development of a software check-out system.

Jan 28 — MSC issue RFP for a design study of low density ablative materials. Contractors required to submit 12 x 12 in. sample tiles.

MSC issue RFP for design and construction of a heating array capable of testing thermal protection tiles at up to 2,500°F.

Jan 31 — Mathematica Incorporated present final report to NASA on an economic analysis of the Shuttle indicating the desirability of proceeding with development and showing the series or parallel burn pressure fed or solid-propellent parallel burn booster to be the most effective.

Jan — Aerospace Corporation present their final report on an Integrated Operations/Payloads/Fleet Analysis conducted for NASA to establish a satisfactory Shuttle traffic model.

Feb 1 — NASA awards a 12 month contract to Loewy/Snaith Incorporated ($99,985) for study of interior layout and decor for the orbiter.

MSC issue RFP for a design study of the Orbital Manoeuvring System.

Feb 4 — MSC award an 18 month contract to the Cornell Aeronautical Laboratory ($175,183) for orbiter landing simulations.

MSFC award an interim contract extension to Rocketdyne ($1 million) for the orbiter main propulsion engine pending the decision of the General Accounting Office on protestations from Pratt & Whitney.

Feb 8 — MSC issue RFP for development construction and test of a thrust chamber for the Orbital Manoeuvre System.

Feb 16 — MSC issue RFP for the design and test of polymer seal materials for storing propellents in the orbiter.

Feb 22 — NASA OMSF design review examines the alternative configurations analysed this far in the second Phase B extension. These included pressure-fed, F-1 high pressure, and 120 or 156 in. solid propellent boosters in a series burn configuration, and twin 156 in. solid propellent, twin pressure

fed liquid propellent, or clustered 120 in. solid propellent boosters with a parallel burn to the orbiter's own propulsion system. Costing analysis indicate the series or parallel burn pressure fed booster would cost about $7,000 million to develop for a launch cost of $6.5 million. The twin solid propellent parallel booster would cost $5,500 million to develop with a launch cost of $10.5 million. The design review also examined a reduced scale orbiter and elected to pursue the original capability of 65,000 lb. to a 100 n.m. due east orbit with a 60 x 15 ft. cargo bay.

Feb 23 — MSC award a 6 month contract to NR ($50,000) for the development of heat resisting structures in the 700-800°F range using Ryton and graphite filaments.

Feb 28 — MSC award a 12 month contract to TRW ($97,000) for development and test of polymer seal materials.

Mar 7 — MSC issues RFP for the study and development of containerised payload systems.

MSC issues RFP for the study of thruster effects on the orbiter's aerodynamic qualities.

Mar 8 — MSC awards a 17 month contract to Lockheed ($299,250) to study and develop a weld-bonding programme for orbiter materials.

Mar 10 — MSC awards a 12 month contract to MDC ($75,000) for the fabrication and test of a heating array for thermal protection materials testing.

Mar 15 — NASA decides to adopt a parallel burn recoverable solid propellent booster concept for the Shuttle.

Mar 17 — NASA issues RFP for the development of a Shuttle and fabrication of the orbiter. Designs to be submitted by 12 May 1972.

Mar 21 — MSC issues RFP for the development of Shuttle mission simulator.

Mar 23 — MSC issues RFP for the study and design of a hypergolic bi-propellent Reaction Control System.

Mar 27 — MSC issues RFP for study of helium regulators for the orbital manoeuvring engines.

Mar 30 — MSC issues RFP for a TV system to assist the remote manipulator system in its operations in the orbiter's cargo bay.

MSC issues RFP for the study of an aeroplane to simulate subsonic flight characteristics of the orbiter. Proposals for submittal by 17 Apr.

Apr 4 — NASA awards a 90 day letter contract to Rocketdyne ($9,800,000) for development and production of the orbiter's main propulsion engine.

Apr 7 — MSC awards 9 month contracts to LTV and United Aircraft Corporation ($126,000 and $98,511 respectively) for EVA studies pertaining to the Shuttle.

Apr 11 — MSC issues RFP for a TV system to display Shuttle activities during flights.

Apr 12 — MSC issues RFP for a hydrazine monopropellent engine for possible application in the reaction control system.

Apr 14 — NASA announces selection of the Kennedy Space Center and the Vandenburg AFB as prime launch sites for the Shuttle. KSC will assume development and flight testing responsibility with Vandenburg phased in toward the end of the decade.

May 4 — MSC issues RFP for the study and development of a series of drawings of a scale model of the orbiter to be used for thermal testing.

May 5 — MSC awards a 12 month contract to MDC ($112,000) for the definition of a visual display system to be incorporated in a mission simulator.

May 8 — MSC issues RFP for the study of foods and galley equipment for the orbiter's crew compartment.

May 11 — MSC issues RFP for the design, fabrication and test of a passenger couch for the orbiter.

May 12 — MSC extends its contract with MDC for the study of an Auxiliary Propulsion System. The $196,000 extension will terminate 15 Oct.

Four companies, NR, MDC, Grumman and Lockheed, present their Shuttle development and design proposals to the Contracting Officer, Space Shuttle Procurment Branch, at MSC. Deadline for submittal was 1.00 p.m. CDT.

MSC issues RFP for design and fabrication of two monopropellent auxiliary power units gas generator assemblies.

May 15 — MSC issues RFP for the study of a cargo handling system for the orbiter called an Attached Manipulator.

May 16 — MSFC reach agreement with US Army Corps of Engineers, Huntsville Division, to provide facility design and construction in support of the Shuttle.

May 22 — MSC issues RFP for a consumables management study for the orbiter.

MSC awards a 9 month contract to Bell Aerospace Corporation ($400,000) for an evaluation of metal-bellows technology for the orbiter's reaction control system.

May 24 — MSC issues RFP for development of a thermal protection system for the orbiter capable of withstanding temperatures of 800-3,000°F.

May 26 MSC awards a contract to GD ($168,000) for a design study of low-density ablative thermal protection system.

Jun 1 MSC extends its thermal protection system contract with LTV to mid-January 1973 with $493,500 applied to the study of Reinforced Pyrolised Plastics.

Jun 6 MSC awards two 12 month contracts to TRW for a $67,138 study of Shuttle sortie payload safety criteria, and a $57,022 study of payload compatability.

MSC awards a 7 month contract to Grumman ($248,500) for the study and development of Closed Pore Insulation materials for thermal protection.

Jun 7 MSC issues RFP to provide prototype helium solenoid isolation valves for test in the orbital manoeuvre system.

Jun 9 MSC issues RFP for a wing leading edge heating array to test thermal protection material up to 3,500°F.

Jun 12 MSFC receives proposals from Irvin, Goodyear, Lockheed, Northrop and the University of Michigan for the evaluation of solid propellent booster recovery techniques.

Jun 20 MSC awards a 4 month contract to Honeywell ($125,000) for the study of an Intertial Measurement Unit programme for the Shuttle.

Jun 30 NASA extends thermal protection system study contracts with 3 companies an additional 6 months. MDC received an additional $350,000, GE $346,000 and Lockheed $345,000.

Jul 1 Fiscal Year 1973 begins with Shuttle appropriations for the next 12 months of $227.5 million from Congress.

Jul 5 MSC awards an 18 month contract to United Aircraft Corporation ($238,000) to design and construct a prototype waste collection system.

Jul 10 MSC awards a 12 month contract to Bell Aerospace Division of Textron ($261,500) for the development, fabrication and test of thrust chambers for the orbital manoeuvre engines in the orbiter.

MSC awards a 15 month contract to Bell Aerospace Division of Textron ($540,000) for study and design of hypergolic bi-propellent engines for the orbiter's reaction control system.

Jul 13 MSC awards a 12 month contract to Singer ($135,530) to determine mission simulator requirments.

Jul 17 MSC awards the Marquardt company a 12 month contract ($181,846) for studies of a helium regulator system for the orbital manoeuvring engines.

MSC awards 6 month contracts to Grumman ($150,000) and Lockheed ($149,000) for the study of a Shuttle Training Aircraft capable of simulating subsonic flight characteristics of the orbiter.

MSC awards Martin-Marietta a contract ($130,000) to design, build and test an orbiter passenger couch capable of providing work, eat, sleep, and relaxation facilities.

Jul 20 MSC awards a 12 month contract to MDC ($181,000) for a definition of orbital manoeuvring system requirments.

MSC awards Grumman ($200,000) a 15 month contract for the fabrication and test of an orbiter heat pipe thermal control system.

MSC awards a 12 month contract to TRW ($84,500) for the definition, design and test of seals used in propellent storage on the orbiter.

Jul 25 MSC extends its contract with Martin-Marietta for the design of an orbiter-configured oven compartment for use in a neutral bouyancy tank. The 10 month extension is valued at $98,000.

NASA announces the selection of NR to begin development of the Shuttle and to assure responsibility for the design, development and production of the orbiter on a cost reimbursement plus fixed fee and award fees contract valued at approximately $2,600 million over the following six years. Runner-up in the competition was Grumman, followed by MDC and Lockheed.

Jul Cost estimates from Phase B contractors indicate a total research and development price of approximately $11,000 million for the fully reusable two-stage Shuttle. Development schedule incorporates a horizontal flight in 1977 and a first manned orbital flight in mid-1978. High costing rates prompt interest in expendable unmanned booster stages.

Aug 2 MSC extends contract with LTV for development of a fail safe design oxidation reinforced carbon thermal protection system for the orbiter's wing leading edge. The contract terminates 20 Apr. 1973.

Aug 3 Grumman visited by NR to discuss subcontracting. Grumman officials visit NR in California on 7-9 Aug.

Aug 4 MSC awards GD an 8 month contract ($92,800) for the study of thruster impingement effects on the aerodynamics of the orbiter.

[To be continued.

SATELLITE DIGEST – 60

A monthly listing of all known artificial satellites and spacecraft, compiled by Geoffrey Falworth. Information is based on that supplied by the Space Department of the Royal Aircraft Establishment, Farnborough, NASA, Satellite News and BIS sources. For information on the derivation of orbital parameters, abbreviations, etc., see July 1972 issue, page 262.

Continued from June issue, page 237.

Name, designation and catalogue number	Launch date, lifetime and descent date	Shape and weight (kg)	Size (m)	Perigee height (km)	Apogee height (km)	Orbital inclination (deg.)	Nodal period (min)	Launch centre, launch vehicle and payload/launch origin
Luna 21 1973-01A 6333	1973 Jan 8.29 7.65 days 1973 Jan 15.94	Irregular frame + 4 legs + 4 cylinders + 3 booms + toroidal cylinder 580	3.43 long 7.75 dia	190	235 Barycentric orbit Selenocentric orbit Lunar landing	51.55	88.68	Tyuratam-Baikonur USSR/USSR(1)
Lunokhod 2 1973-01D	1973 Jan 8.29 7.65 days 1973 Jan 15.94	Cylinder + 9 wheels + 2 booms + panel + antenna 840	1.35 long 1.25 dia 1.15 high	190	235 Barycentric orbit Selenocentric orbit Lunar landing	51.55	88.68	Tyuratam-Baikonur USSR/USSR(2)
Cosmos 543 1973-02A 6339	1973 Jan 11.42 12.9 days (R) 1973 Jan 24.3	Sphere-cylinder 4000?	5 long? 2.44 dia	203	311	64.99	89.65	Plesetsk USSR/USSR
 1973-02C 6346	1973 Jan 11.42 16.76 days 1973 Jan 28.18	Sphere?	2 dia?	167	290	64.98	89.06	Plesetsk USSR/USSR(3)
Cosmos 544 1973-03A 6343	1973 Jan 20.15 8 years	Cylinder + paddles	2 long? 1 dia?	510	548	74.03	95.23	Plesetsk USSR/USSR
Cosmos 545 1973-04A 6348	1973 Jan 24.49 5 months	Ellipsoid 400?	1.8 long? 1.2 dia?	269	495	71.00	92.20	Plesetsk Cosmos USSR/USSR
Cosmos 546 1973-05A 6350	1973 Jan 26.49 10 years	Cylinder + paddles?	2 long? 1 dia?	575	614	50.66	96.51	Tyuratam-Baikonur USSR/USSR

Supplementary Notes:

(1) Luna 21 further tests onboard spacecraft systems, continues scientific investigations of the Moon and circumlunar space and acquires lunar surface data. Following launch ground controllers at Soviet Union's manned spaceflight centre, Zvezdnoy Gurodok, monitoring Luna 21's flight trajectory acquired engineering telemetry shortly after translunar injection indicating that one of the spacecraft's descent stage landing legs had failed to deploy nominally but additional analysis indicated a false telemetry signal and ground commands subsequently deployed Lunokhod 2's solar cell array to acquire additional power throughout the mission until powered descent to the lunar surface. Following a midcourse correction manmanoeuvre during 1973 Jan 9 during which Lunokhod 2's solar cell array was temporarily retracted and Luna 21's decent stage propulsion system fired on ground command, the spacecraft's optical sensors mounted outside Luna 21 descent stage's instrument compartment subsequently acquired Earth and Sun, Luna 21 performed nominal re-orientation manoeuvres utilising descent stage-mounted orbital correction and stabilisation thrusters and, following Lunokhod 2's temporary solar panel retraction, the spacecraft's descent stage propulsion system fired during 1973 Jan 12 to place the spacecraft in a selenocentric orbit ranging from 110 km at aposelene to 90 km at periselene inclined 60°.0 to the Moon's equator every 118 minutes. Radio communications sessions between the spacecraft and Soviet data acquisition centre during translunar coast and selenocentric orbit insertion manoeuvres indicated that all onboard systems were operating nominally. Lunokhod 2's solar cell array was again temporarily retracted and Luna 21's orbital correction systems were activated during 1973 Jan 13 and Jan 14 lowering the spacecraft's selenocentric orbit to one ranging from an aposelene of 110 km, periselene 16 km and inclination 60°.0 to the lunar equator each 114 minutes. During 1973 Jan 15 Soviet ground stations conducted commucations sessions with the spacecraft, determined exact orbital parameters of Luna 21 and transmitted orientation commands to Luna 21's onboard computer and, following minor midcourse corrections and programmed manoeuvres, the spacecraft's descent propulsion system subsequently fired at periselene during the spacecraft's 41st revolution about 255 km from nominal landing site for about 270 sec at 1973 Jan 15.93 over lunar Earthside until Luna 21 reached the 3-km altitude when onboard stabilisation systems were activated until Luna 21 reached an altitude of 0.75 km and the required descent velocity when onboard vernier engines were ignited on command to align the spacecraft with local vertical. Responding to radar altimeter-generated commands Luna 21 descent stage's propulsion system then re-ignited and onboard radar descent system-commanded variable thrust rocket engine fired until the spacecraft was about 20 metres above the lunar surface and descending at 2.5 metres per sec. Descent propulsion system was then de-activated, vernier engine ignition commenced until onboard radar systems indicated a spacecraft altitude of about 2 metres above the Moon, a zero horizontal velocity and a rate of descent of less than 2.5 metres per second at which time all propulsion systems were terminated and the spacecraft landed on the Moon at 1973 Jan 15.94 at approximate astronautical selenocentric latitude 26°30' north, longitude 30°36' east inside the crater Lemonnier about 1690 km northwest of Lunokhod 1's landing site and less than 160 km due north of Apollo 17 descent stage (1972-96D) landing site. Ground-commanded telemetry from the spacecraft received at Soviet ground stations indicated that all onboard systems were operating nominally; Luna 21 descent stage held the USSR state flag, pennants with bas reliefs of Lenin, Soviet Union's state coat of arms and inscriptions denoting the USSR's 50th anniversary. Orbital data at 1973 Jan 9.0, Jan 9.5, Jan 13.0 and Jan 15.95.

(2) After landing on the Moon attached to Luna 21's descent stage (1973-01A) at 1973 Jan 15.94, routine testing of onboard systems and operations and initial TV survey of the surrounding lunar surface was followed by Lunokhod 2 moving off Luna 21's

descent stage down a descent stage-mounted ramp at 1973 Jan 16.05 and about 5 metres across the lunar surface being subsequently deployed adjacent to the descent stage during systems and operational test and initial panoramic TV photography initiation. Main objectives of the spacecraft are to establish and use a lunar surface transportation system, conduct scientific investigations of the lunar surface at various distances from Luna 21, further test automatic operation of remote-controlled lunar surface mobile vehicles under lunar surface conditions, obtain high-resolution observations of solar, galactic and extra-galactic X-ray sources from the lunar surface using spacecraft-mounted instrumentation consisting of a zenith-oriented background X-ray spectrometer and associated measuring, amplifying and data storage systems coupled to Lunokhod 2's science telemetry subsystem, acquire lunar magnetic field data and magnetic properties of individual lunar rocks using an onboard forward-viewing, boom-mounted, 2.5-metres long magnetometer, measure zodiacal light during lunar daytime and galactic and interplanetary emissions during lunar night-time with a lensless electron telescope photometer system, similar to instrumentation aboard Cosmos 51 (1964-80A) and Cosmos 213 (1968-30A) viewing upwards from Lunokhod 2's forward experiment area to determine lunar dust concentrations near the Moon's surface at visible and ultraviolet wavelengths in studies of feasibility of performing astronomical observations from the Moon and study correlations between solar corona, zodiacal light and galactic ultraviolet emissions, acquire lunar surface composition data using onboard base-mounted Rifma spectrographic instrumentation comprising enclosed radioactive source irradiating upper lunar surface layers immediately below the spacecraft which respond by emitting X-ray quanta detected and measured by the Rifma instrument which also distinguishes between solar radiation-produced and instrumentation-produced emission, and determines quanta spectral characteristics to determine lunar regolith transition region between lunar mare and continental areas near the landing site, obtain high-resolution stereo lunar surface TV photographs using two downward-pointing, 180°-field of view, forward-viewing TV cameras transmitting one frame each 3 sec incorporating an oscillating mirror system reflecting light into an onboard lens system coupled to a photoelectric multiplier converting images into electronic signals for transmission to Earth, obtain lunar panoramic TV photography transmitting complete 360° panoramas each 30 min. and operational lunar surface photographs in support of Lunokhod 2 traverse operations using a boom-mounted, forward-viewing, steerable, 50°-field of view, small-frame TV camera incorporating a vidicon faceplate recording and subsequently transmitting navigational TV images of the forward lunar surface area each 3 to 20 sec, and utilise a French, forward experimentation area-mounted, corner-cube, TL-2 laser reflector in further investigations of lunar orbital parameters Earth-Moon distances and in support of geodetic studies. Lunokhod 2's cylindrical main structure holds scientific instrumentation, telemetry transmitting to Earth on ground command through a deployable, Earth oriented, omni-directional antenna, onboard TV camera systems and associated electronics, thermonuclear thermal control systems consisting of passive screen and vacuum heat insulation, active self-regulating cooling systems and isotopically-heated inert gas system to maintain internal electronics at operating temperatures, cooled gas being recirculated in a closed-loop system over an isotopic heat source and white, solar-reflective coatings and excess-heat radiators deployed and activated only during sunlit operations, improved driving mechanism for Lunokhod 2's individually electrically powered, eight-wheel chassis system including braking systems permitting either of four left- or right-side wheel combinations to be slowed independent of remaining wheels, and backup engineering and telemetry subsystems. Preliminary telemetry from the spacecraft indicated that all systems were operating nominally. Further reports on this spacecraft appear in 'Milestone' and 'Space Report' in this journal. Orbital data at 1973 Jan 9.0, Jan 9.5, Jan 13.0 and Jan 15.95.
(3) Ejected from 1973-02A at 1973 Jan 23.

Decays:
Cosmos 200 (1968-06A) decayed 1973 Feb 24.48, lifetime 1862.56 days.
Cosmos 523 (1972-78A) decayed 1973 Mar 7, lifetime 153 days.
Intercosmos 8 (1972-94A) decayed 1973 Mar 2, lifetime 92 days.

Amendments:
Operations 8285 (1969-65A) lifetime is 1253.26 days, descent date is 1973 Jan 4.72.
Pac 1 (1969-68B) lifetime is 8 years.
Cosmos 300 (1969-80A) size is 7 long?. 3.9 dia.
Cosmos 305 (1969-92A) size is 7 long?. 3.9 dia.
Dial 1 (1970-17A) lifetime is 7 years.
Operations 5346 (1970-46A) lifetime is 5 years.
Molniya 1Q (1970-77A) lifetime is 3.3 years.
1971-67G lifetime is 10 years.
Cosmos 526 (1972-84A) perigee is 273.

SPACE REPORT

A regular monthly review of Space Events and Technical Trends

INDUSTRIAL SPIN OFF

Heat pipes, first used in NASA spacecraft and in cooling nuclear reactors, are finding rapidly growing industrial and household use. New developments in the technology were reviewed at a symposium sponsored by the Technology Application Center at the University of New Mexico, Albuquerque, New Mexico, on 8-12 Jan.

Basically the heat pipe is a sealed tube from which air has been exhausted. It contains a small amount of liquid and a wick. Evaporation, condensation, and surface tension move the vapourising fluid in the wick and transfer the heat from one area to another without the need of a pump. This highly efficient equipment can transport heat at approximately 500 times the rate possible with the best solid conductors, with minimal temperature loss.

The heat pipe has recently been applied domestically in recovering and recirculating heat from chimney flues, increasing the efficiency and economy of many types of home heating plants approximately 10%. The firm developing this household application expects to market the device widely in the near furture.

Large heat pipe units are being considered for use beneath the foundations and buildings in Arctic and subarctic regions, to prevent summer thawing of permafrost in an effort to keep structures in plumb and to eliminate damage to their foundations.

A heat pipe application now on the market and familiar to many housewives is a 'cooking pin' for distributing heat evenly through meat during the roasting process. A heat pipe for lowering the oil temperatures in motorcycles is now being offered commercially and a wide variety of other commercial applications are in the final stages of product development.

Heat produced in many industrial processes and in internal combustion engines is often largely wasted in present equipment. Heat pipes researchers are studying ways of putting this waste fuel to beneficial use, with attendant reduced fuel consumption and atmospheric pollution.

EARTH-SURVEY SKYLARKS

Two British Skylark rockets were launched from central Argentina on 22 and 28 March on Earth-survey flights to identify mineral and agricultural resources. The pointed nosecones included four cameras with different lens and films permitting an overview of nearly 200,000 square miles of Argentina's main agricultural region.

The rockets, fired from a transportable launcher at Mercedes Air Force Base, reached altitudes of up to 150 miles. The aim of each firing was to photograph a circular area of 500 miles diameter before the separated payload returned to Earth by parachute for recovery and study of the photographic payload. In each case the rocket casing was also recovered by parachute.

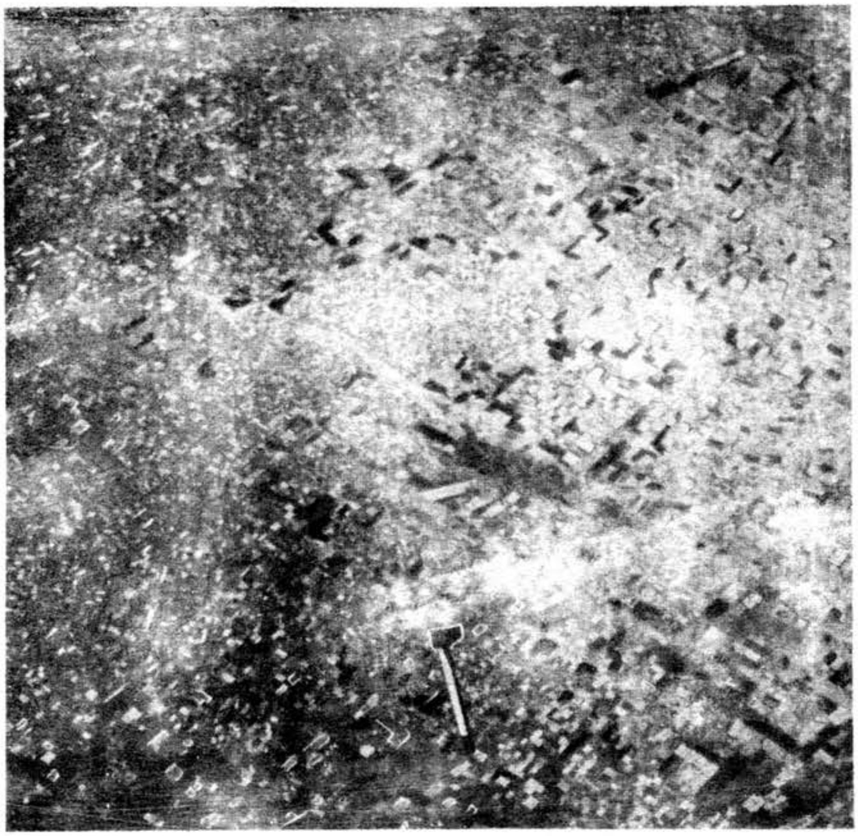
Terrain surveyed in each flight ranged from cultivated areas to grassland and mountains as a demonstration of Skylark's capability as a survey tool for the study of geology, vegetation and soil types, crop measurement, water resources and drainage patterns.

The programme was conducted by a combined team from the R.A.E., Farnborough, The British Aircraft Corporation Electronic and Space Systems Group and a team of Reading University scientists who are collaborating with Argentinian scientists. It was the first time that Skylark rockets have been launched away from an established rocket range, although 300 firings have taken place to date in British and European scientific space research programmes.

The camera payload aboard each rocket consisted of three motorised Hasselblad 70mm cameras and an F24 aerial camera. Two of the 70mm cameras (designated 'B' and 'C') were equipped with Zeiss Sonnar f/4 150mm lenses and the third ('A') with a Zeiss Sonnar f/6. 250mm lens. Kodak Aerial Colour Film ('Estar' Thin Base) SO242 - an extremely fine grain, slow speed, high definition colour reversal aerial film with high contrast and good colour saturation to decrease the effects of atmospheric haze – was used in cameras 'A' and 'C'. The ground resolution in frames exposed in camera 'A' was 20 metres. Kodak 'Aerochrome' Infrared Film 2443 – a 'false colour' emulsion – was used in camera 'B' with a 'Wratten' 12 filter. Exposures were based on tests flown previously at 10,000 metres in an aircraft under comparable lighting condition.

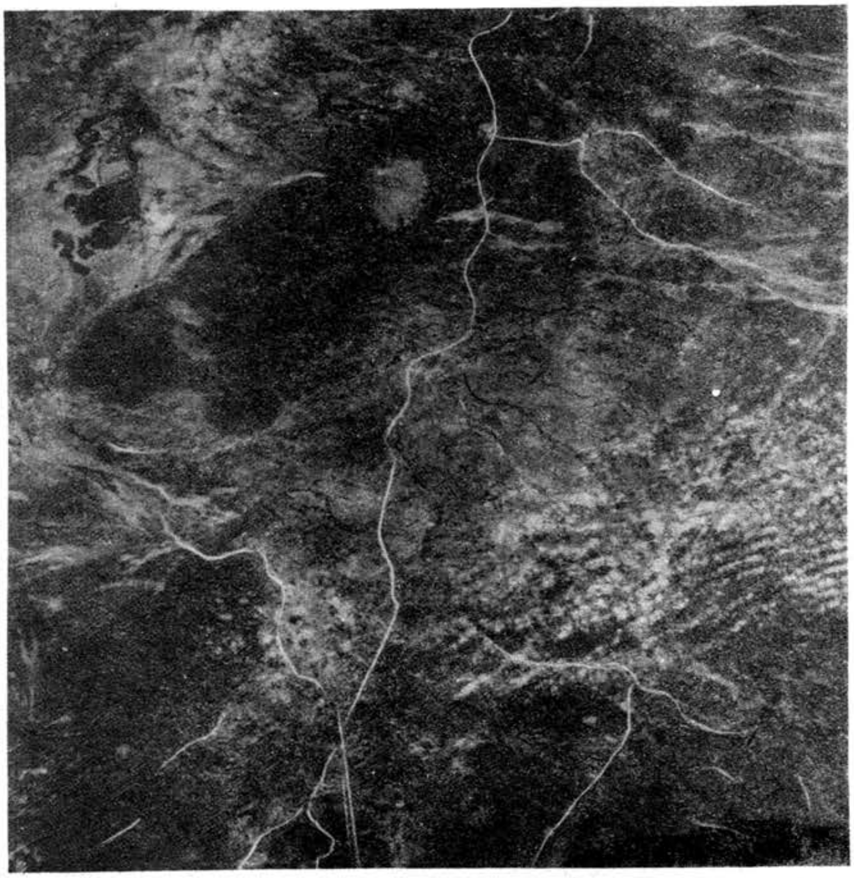
The F24 camera was fitted with a Ross EMI f/4 127mm lens. In the first rocket was Kodak 'Aerochrome' Infrared Film 2443. The F24 camera in the second rocket had Kodak 'Plus-X' Aerographic Film, Type 2648 ('Estar' Base). This is a general purpose material for aerial photography, with extended red sensitivity, high speed, high contrast, fine grain and considerable exposure latitude.

The maximum capacity of each of the 70mm cameras was 80 frames thus giving a potential total of 240 70mm frames per launch. The maximum capacity of the F24 camera was 100 frames on 5½ in. film. During the missions it was possible to secure imagery of an area of approximately 400,000 km^2. The flight colour films and duplicates – made by the Royal Aircraft Establishment at Farnborough on Kodak 'Ektachrome'



A unique photograph taken during the recent Earth resource survey campaign in Argentina using Skylark rockets; the rocket payload carrying the cameras has begun taking photographs of the Earth below and in this picture can be seen the spent rocket motor just before its recovery parachute opened. Below is a cultivated area in the Southern part of the Province of Cordoba. This one photograph covers an area of about 30,000 km^2. It was taken with a Hasselblad camera, 150 mm. focal length lens with Kodak Aerochrome infra-red false colour film 2443.

British Aircraft Corporation



Total area surveyed by Skylark rockets in central Argentina covered a circular area of more than 700 km diameter. Each of two rockets carried four cameras, an F24 aerial survey camera and three Hasselblads. This photograph was taken by a Hasselblad using true colour high resolution film (Kodak SO 242) and shows an area of some 16,000 km^2 north west of the launch site at Mercedes in the Province of San Luis. The mountain range Alto de Panacos runs diagonally left to right of the picture. Puffs of cloud and their shadows are seen on the right. Photographs are being analysed by scientists from Reading University, Department of Geography, in collaboration with Argentinian scientists from the Comision Nacional de Investigaciones Espaciales as part of a research programme into monitoring the Earth's resources by remote survey. The ER Skylark was first tested at Woomera, South Australia, on 27 March 1972 (see *Spaceflight*, August 1972, pp.282-286).

British Aircraft Corporation.

Aerographic Duplicating Film ('Estar' Base) SO-360 – were processed in a Kodak 'Ektachrome' RT Processor, Model 1411.

The payloads of the two rockets comprised multispectral sensing units broadly similar to several used by NASA during Apollo mission experiments, notably SO65 flown during Apollo 9 in March 1969. Valuable experience in the use of the Skylark rocket as a stabilised camera platform for Earth resources sensing was gained in March 1972 when one was launched over an area in South Australia. In the UK analysis and interpretation of the results of this mission have been undertaken by a group from the Geography Department at Reading University under Professor R.A.G.Savigear.

The Argentine experiments had two major objectives. The most important short-term aim was to secure a land use/crop inventory of the cultivated areas photographed. The longer term objective was an evaluation of the rocket imagery as a tool for mapping and resources survey – including the study of geological structures; vegetation mapping and its relationship to soil conditions, water resources and minerals; soil salinity; drainage networks and road networks. Specialists from Reading University's Department of Geography had previously visited the site in Argentina to study at close-hand and in detail selected test areas of the region to be photographed from space.

While most attention has been directed at major Earth sensing experiments (both manned and unmanned) *from orbit*, the availability of a stabilised platform on a sounding rocket has certain advantages – particularly for developing countries where maps and other resources data are usually not as detailed or extensive as in other countries. The rocket has the space vehicle's advantage over an aircraft of providing small-scale data – *albeit* with less resolution – of the terrain quickly and under comparable synoptic conditions. At the same time, the rocket has the advantages over orbiting space vehicles of no restrictions resulting from orbital characteristics – for example, passing over a particular point only once every so many days; the ability to sense a target area under optimum conditions, for example, absence of cloud cover; the facility of varying sensors from one launch to another; and far lower costs together with much shorter planning times, features which have been further emphasised by the availability of a new portable launcher for the Skylark designed by the British Aircraft Corporation and made at R.A.E., Farnborough.

NEXT MONTH

The August issue of *Spaceflight* will include a major illustrated feature on Mars by C. A. Cross, including the first publication of the new maps he has prepared from Mariner 9 photographs. There will also be an interview with Academician Boris Petrov on the future of the Soviet manned space programme, and an article by James E. Oberg on 'Missing Cosmonauts from the Class of 1960'. We also hope to include a review of the NASA budget for Fiscal Year 1974.

SOCIETY NEWS

Space Probe from Epsilon Boötis

International interest continues to surround the paper, 'Space Probe from Epsilon Boötis' by Duncan A. Lunan, M.A., which appeared in the April 1973 issue of *Spaceflight.* The author defended his thesis before a packed meeting of the Society at Caxton Hall, Westminster, on 29 March.

The meeting received wide coverage by press and radio, and the entire proceedings were filmed by the Columbia Broadcasting System (CBS) for TV presentation in the United States.

So enthusiastic has been the response to this paper, which began as a contribution to our 'New Frontiers' series, that newspapers and radio stations – particularly in the United States – have been flooded with requests for further information.

Although some press reports have suggested that the paper offered proof of the existence of a star probe from another civilization, it should be emphasised – as was done in the original presentation – that the author's objective was merely to give a positive example of the way in which a hypothetical star probe might open communications by responding to coherent broadcast signals. Mr. Lunan chose the anomaly of long-delayed echoes as an example of the kind of response one might expect from initial contact between alien intelligences, the logic of a star map presentation being overwhelming.

In the introduction to his paper, the Editor wrote: 'Although many will doubt that sufficient evidence has been presented to support this hypothesis, the logic of Mr. Lunan's work is of interest in its own right as a contribution to the problem of interstellar communication. We leave the reader to decide for himself: (a) the reality of the long-delayed echoes as anything but a purely natural phenomenon; and (b) the validity of the interpretation that has been placed upon them'.

Mr. Kenneth Gatland (Chairman) opened the meeting on 29 March by pointing out that three years ago the Society had begun a series of studies, under the heading of 'New Frontiers', which looked beyond present technologies to the future of space research and exploration. At that time, it was pointed out that one of the most compelling quests would be the search for evidence of 'intelligence' elsewhere in the Universe.

Mr. Gatland continued: 'Regular readers of our publications will already know the course that this work has taken. We have examined in some detail, the various problems involved in filtering signals from the surrounding star fields, which may bear the imprint of intelligence, and have reported on American and Soviet activities in this field.

Serious interest in seeking evidence of extra-terrestrial civilizations began in 1959, when Cocconi and Morrison suggested that the most universally accepted wavelength for interstellar communication would be 21 cm., the radio emission line of neutral hydrogen in space. Any investigator of the Universe – human or otherwise – would be aware of this.

The first attempt to put the idea into practice was made in 1960 by a team of radio-astronomers under Dr. Frank Drake at Green Bank, Virginia. For some three months an 85 ft. radio telescope, tuned to 21 cm, was aimed at two stars, Tau Ceti and Epsilon Eridani.

Although there were one or two false alarms, no signals which could be identified as 'intelligent' were located and it was concluded that further work would require much more sensitive equipment.

In our publications, we have also drawn attention to the importance of co-ordinating searches of this kind on an international basis, and in this connection the CETI Conference held in Soviet Armenia towards the end of 1971 brought together radio-astronomers and others from many countries, principally, of course, the United States and the Soviet Union.

The most active work at present is, in fact, in the Soviet Union where Dr. Vsevolod Troitsky of the Radiophysical Institute in Gorky has been concentrating on selected stars within 100 light years of our Solar System using special equipment operating in the centimetre and decimetre bands.

In all this work one must, of course, take the utmost care to eliminate all spurious sources which might otherwise be suspected of being artificial, and this obviously requires the most painstaking research. One recalls, for example, the excitement that was raised when pulsars were first discovered, which really did look like flashing call-signs in space.

The Soviet programme is already more than four years old and much of the time has been spent in eliminating from the background noise of the galaxy signals of natural origin which might, for example, have geo-magnetic causes.

Because of the immense problems involved in searching the electromagnetic spectrum for signals which bear the imprint of intelligence, the Soviet radio-astronomers have been looking particularly (to use their own words) 'for powerful impulsive radiation which might be the result of astro-engineering activities by an advanced civilization'.

In these experiments, four widely separated stations work together. One is in the Crimea, another in Gorky, a third in the far north-west of the Soviet Union at Murmansk, and a fourth in the Ussuri territory of the Soviet far east. Such wide spacing of the receivers makes it possible to rule out all signals which may be due to local radio interference and allows the operators to concentrate only upon those signals which are global in character. The programme, which is concentrating on wavelengths of 3 to 50 cm, is still under and we hope to report on this at some later date

There are of course other ways in which we might encounter extra-terrestrial intelligence, and one is that we might discover some kind of space probe or machine artefact that someone else has deliberatly sent our way. Now, on balance, we have to confess that this is a rather slim chance. But on the other hand, we have Professor Ronald Bracewell of Stanford University referring to this possibility while trying to assess unusual radio signals received in the 1920's and which were characterised by having long delayed echoes.

When Bracewell made this comment in 1960, attempts to find meaningful patterns in the signal delay times proved fruitless. But just recently a new reading of the signals by the young Scottish researcher Duncan Lunan suggests that they do convey meaningful patterns. It is Lunan's submission that they can be presented as star constellations of the Northern Sky.

Mr. Lunan would be the first to admit that the case for an alien artefact in our midst is far from proven. One has to ask if the long-delayed echoes which have been recorded, and which by some accounts are still being received, could have a natural explanation. Are they, for example, produced by some beam-plasma effect when the Earth's magnetic field is disturbed by unusual solar activity? If they are then his interpretation must be purely subjective. It is for you to judge if he has made a case which will stand up to the full weight of scientific examination.

To help solve this problem a series of special radio experi-

ments has been mounted by a small team under Mr. A.T. Lawton, manager of the computer division of E.M.I., who is also a Fellow of this Society'.

The aim is to repeat the experiments carried out by Störmer and van der Pol but at different wavelengths to those originally used. This entails the use of powerful commercial apparatus with which the team hope to produce, measure and study long delayed echoes (L.D.E's).

Mr. Lawton stressed that in this matter one had to be completely open minded since there were at least 3 possible natural explanations for L.D.E's. These involved ionospheric and Van Allen Belt anomalies, reflections from the Lagrangian points of the Earth and Moon, and reflections from the Moon itself.

Our knowledge of the ionosphere, Mr. Lawton emphasised, is by no means complete, particularly under conditions of severe solar ionisation, and if the Lagrangian areas have been radar sounded it appears that no information has been published.

As can be imagined, Mr. Lunan's thesis has not been without its critics and, indeed, it was part of the exercise to expose the ideas presented to the full glare of scientific examination. As it turns out, the study has been stimulating in its own right in drawing attention to specific problems connected with interstellar flight.

By focussing on a particular double star (Epsilon Boötis) we have been led to examine a type of system which at first seems most unlikely as a breeding ground for intelligence, for it probably has a much shorter life history than our own, with unfamiliar stellar characteristics. It has also revealed how sparse and contradictory is our present knowledge of stars which lie within little more than 100 light years of our own system. Extrapolation of the thesis has also shown how effective a double star system would be in building up high departure velocities using the Dyson gravitational effect of two components, making appreciable savings in transit times.

Many people have asked for more details of the star field concerned in the theory.

The diagram (Fig. 1) depicts the constellation Boötes (redrawn from Norton's Star Atlas Epoch 1950) and clearly shows the Proper Motion and direction of α Boötis – Arcturus.

Arcturus has this large Proper Motion simply because it is the nearest known star in the constellation (various references quoted 38-42 light years). It is also one of the brightest stars in the sky (magnitude 0) and may easily be found by first locating the Plough and looking for the 'handle' formed by Mizar and Alkaid. Looking downward and to the left (south-east) on an imaginary straight line drawn through these 'pointers' will locate Arcturus as a bright orange star. Epsilon Boötis is a lesser yellow star immediately above and to the left. Arcturus, Epsilon and Delta Boötis almost form an imaginary horizontal straight line.

The Proper Motion is shown as being to the south-east. Ref. 1 actually *shows* the motion to the south-east, but *states* (in error) the motion as south-west. This error was unfortunately perpetrated in Lunan's paper which is otherwise correct in showing the motion in this sense, which clears up a point raised by Mr. Alan Bond at the Caxton Hall meeting.

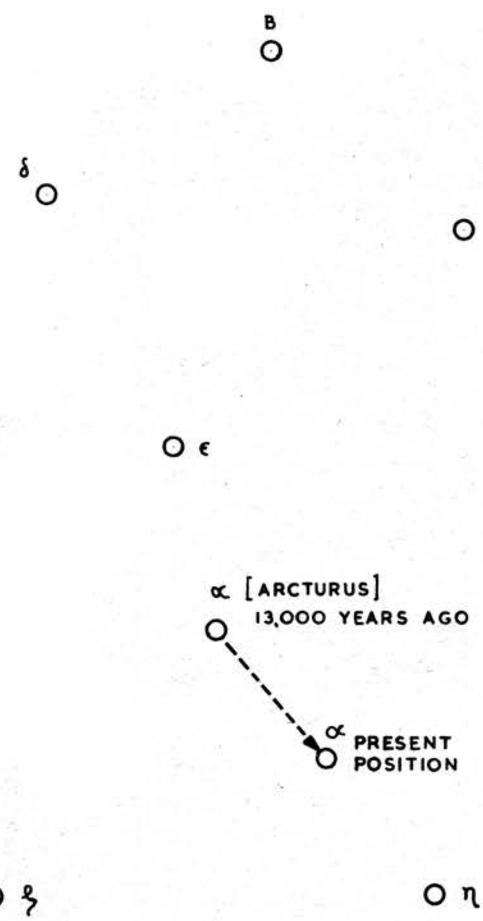


Fig. 1. The Constellation of Boötes.

CORRESPONDENCE

Space Probe from Epsilon Boötis

Sir, My attention was drawn to the ideas of Mr. Duncan Lunan concerning a space probe from Epsilon Boötis by the mention of Professor R. N. Bracewell's name in the *Sunday Telegraph* article of 4 February 1973. I wrote to Professor Bracewell, whom I have known for many years, and received a reply which suggested to me that he saw no evidence that the echo-delays used by Mr. Lunan came from a space probe. Bracewell also sent me a copy of the typescript of Mr. Lunan's article, a modified version of which has appeared in the April 1973 issue of *Spaceflight.* It provides one of the most remarkable examples of the manipulation of data which I have come across.

Mr. Lunan states on p.122 that radio echoes with a delay of 3 seconds were observed on 11 October 1928 by Hals in Holland. The delays then began to vary in duration 'ranging from 3 seconds all the way to 15 seconds'. Later that day, van der Pol observed the sequence of echo-delays given in the penultimate paragraph of p.122, and Störmer also observed on that day the four sequences listed in the third paragraph of p.125.

Mr. Lunan does not describe in detail how he made up his Fig. 1 but I have constructed it by the following procedure: a number, called the 'pulse sequence' (PS) by Lunan, is assigned to each of van der Pol's echo-delays as shown in Table 1. A first manipulation of the data consists in assigning the same PS number to each member of the pairs of double echoes (PS numbers 2 and 8). In his original typescript, Mr. Lunan had shown that if consecutive PS numbers were assigned to each member of a pair, the diagram was too distorted to serve his purpose.

TABLE 1.

Pulse Seq. No.	1	2	2	3	4	5	6	7	8	8	9	10	11	12
Echo-delay (sec.)	8	11	15	8	13	3	8	8	8	12	15	13	8	8

A second manipulation consists in treating the two numbers 'PS number, echo-delay' as the rectangular co-ordinates of points, the *same scale* being used on each co-ordinate axis. The result is Fig. 1 without the point marked X. The only feature of interest which this figure exhibits is that it shows that 8-second delays were more frequently observed than were delays of other durations. However, two arbitrary elements of interpretation now appear. The first is that all points on echo-delay diagrams like Fig. 1 do not represent stars but only certain points, selected by Mr. Lunan, possess this interpretation. Secondly, the assertion is made, without any supporting evidence, that the line of points in Fig. 1 corresponding to the 8-second delays do not represent stars but constitute a 'barrier'. A third manipulation of the data then occurs and consists of the horizontal transfer of the 3-second delay point to the 13-second delay position marked X, apparently because 8 - 3 = 13 - 8 = 5. The assertion is then made that the points of Fig. 1, to the right of the 'barrier', represent the constellation Boötes even though the point representing Arcturus is very much out of position. It is next asserted, by allowing for the (estimated) proper motion of Arcturus, that the points represented the constellation as it would have appeared 13,000 years ago. Fortunately for Mr. Lunan, there was no astronomer around at that date to make a record by which this assertion can be checked.

It may be remarked that many PS numbers preceding No. 1 of Fig. 1 could also have been assigned to the 3-second delay because it was being observed by Hals before the van der Pol sequence began. Transfer of these additional points across the 'barrier' would have made very little sense of a Boötes identification.

Manipulations of Störmer's data of 11 October 1928 also underlie Lunan's figure on p.127 (note that the captions of the figures on pp. 126 and 127 have been interchanged)*. I plotted the points of Störmer's first sequence given on p.125 (delays 15 to 8;) : the resulting diagram could only be brought into a semblance of a map of the Ursa Major region, as in the figure on p.127, by following Lunan's selection, and alteration of position, methods thus: (i) the points A and B do not represent stars but the others do; (ii) the point PS = 8, delay = 10 must be moved to PS = 8, delay = 8 and the point PS = 11, delay = 8, to PS = 11, delay = 10. This is done because it is said that these two delays were subject to the large 'errors' of -2 seconds and +2 seconds respectively, whereas the delays for the remaining points contain no errors at all. How Mr. Lunan knows this to be the case is not explained. Furthermore, when I plotted the diagrams for all Störmer's data of 11 October, I was unable to detect any resemblance to either the whole, or to parts, of the star map on p.126, even with a liberal use of 'errors' in the delays to move around the points in the diagrams.

On 24 October 1928 van der Pol observed 21 echoes which he reported by publishing a diagram in *Nature,* incorrectly quoted by Mr. Lunan as being on p. 875 of Vol. 122. It is in fact on p. 878. This diagram is Mr. Lunan's Fig. 2(b). In his typescript, he revealed his 'PS number versus echo-delay' diagram for this set of data and it again shows a random scatter of points. Mr. Lunan provides no evidence that his identification of this diagram with the star chart shown in Fig. 3 is unique and cannot be duplicated in many other places on the celestial sphere. In any case he has to assert that the four points marked A, B, C, D do not represent stars and he has also to 'rotate' the diagram and make unspecified 'allowance' for proper motion before an identification is achieved.

Manipulation of evidence in these various ways does not add up to a scientific procedure and, indeed, would be rejected out of hand in any court of law. What has happened is clear: Mr. Lunan, without any evidence at all, has decided that a space probe from Epsilon Boötis was responsible for the echo-delays. He has then manipulated the data in such a way as to support this pre-conceived idea. Therefore his charts provide no evidence that any space probe, whether from Epsilon Boötis or elsewhere, was connected with the echo-delays.

These criticisms can be safely ignored by Mr. Lunan and his co-investigator Mr. Anthony Lawton of E.M.I. The press and the BBC have already publicised their ideas and this publicity will continue. I make this prediction because I have noticed that the media are uninterested in the validity of the evidence for an assertion in astronomy but are only concerned with the amount of sensationalism that can be extracted from the assertion.

G. C. McVITTIE, O.B.E., Ph.D.,
Honorary Professor of Theoretical Astronomy, University of Kent.

* *Unfortunately, the diagrams which appeared on pages 126/7 were transposed during production so that the captions read left to right and vice-versa.*

Duncan Lunan replies:

In my paper it was postulated that if a probe was trying to contact us in the 1920's (as Professor Bracewell suggested in 1960) and 'If the signals are an attempt at communication, what meaning are they intended to convey?' I attempted to answer the question as a logical exercise.

This was emphasised by the Editor in his introduction to the paper.

I should also emphasise that I do not seek to conceal my 'manipulation of data', nor to suggest that there is any evidence to justify them. In the matter of the afternoon echoes of 11 October 1928, for example, the question I set myself to answer was: 'How few changes would have to be made in the record, since we know it is not accurate, in order to produce a meaning consistent with that suggested for the later sequences?'. The tentative answers suggested may be incorrect even if the probe does exist.

The original caption for the diagram on p. 126 read 'A tracing of a star map, showing the approximate area covered ....'. That is to say, the drawing is a *real* star map and not a representation of any 1920's results. Since the map in question is of the modern epoch, projected about the present motion of the celestial pole, no fit with the 1920's echo patterns would be expected if my interpretation is correct. In any case the map in question shows stars down to magnitudes 5 and 6, for which there are not enough dots in the echo sequences if they do really represent star maps.

Regarding the suggestion that I pre-judged the issue, I am not sure why anyone with such a preconceived idea should pick Epsilon Boötis as a life-supporting star. I can state with confidence that when I first looked into this matter, I did not believe that the echoes came from a space probe at all. I do not know quite how to make that statement convincing, but may I suggest some possibilities which would demand the partial or total revision of the interpretation:

(1) It was pointed out at Caxton Hall that I had given the Proper Motion of Arcturus as south-west, while showing it as south-east. The mistake proved to be in the diagram and caption of the source consulted, and other sources indicate that the true direction is south-east as shown. Had it proved to be south-west, or any other direction, the entire interpretation would have had to be reconsidered if not scrapped.

(2) Our efforts to trace the missing part of the 24 October 1928 echo sequence are continuing. If the record is found and does not match the star map prediction, then it may mean that 'All that's spoke is marred', or put the interpretation of the supposed Boötes figure in an entirely new light.

(3) A thorough check of reference tables has revealed astonishing discrepancies in the spectral types and distances quoted for Epsilon Boötis. The range of spectral values is from AO to K2 for the major Sun and AO to G8 for the minor. A recent source, supposedly the most reliable, gives the major Sun as K1 orange giant and the minor as AO, distance 103 light-years. But I understand that an AO Main Sequence star is of approximately the same absolute magnitude as a K1 giant, while a giant AO star would obviously be far *brighter* than a K1 giant. Yet the various references give the apparent magnitudes of the major and minor suns as about 2.3 and 6.3 respectively. 2.3 is an acceptable apparent magnitude for a K1 giant 103 light-years away, but is not compatible with an AO companion at the same distance. F6 would be a more reasonable value for the minor sun, and would fit the white colour reported by some observers where most call the minor sun blue. It would also tie in very nicely with and implication in the diagrams, as I interpret them, that when on the Main Sequence the major Sun was F5.

In the last analysis, however, Mr. Lawton's experimental programme aimed at finding the probe, if it exists, will be the most important test of all. He himself maintains an open mind on the possibility of the probe's existence, but points out that even if he shows that no probe exists, then speculation on it can be terminated and perhaps the true origin of long-delayed echoes will have been established.

Mr. Anthony Lawton comments:

Professor McVittie's letter raises a number of interesting points – I for one am glad that the articles have stimulated such a response.

To reply, in the first instance, the aim of Lunan's paper was to put forward a hypothesis providing a possible explanation of the long sequences of echoes recorded by responsible authorities in the late 1920's. In particular, he was outlining possible logic behind the sequences.

Professor McVittie's letter contains an initial error in the statement ending 'on 11 October by Hals in Holland'. Lunan's short paper to Bracewell is specific in correctly stating 'Engineer Hals of *Oslo* first heard these 3 second echoes in 1927'. For an accurate and complete account I would refer Professor McVittie to Störmer's book 'Polar Aurorae' pp. 173 - 182.

McVittie's Table 1 is not a 'manipulation of data', it is an alternate method of presentation, logical if one pulse did produce 2 echoes – either natural or artificial.

When scaling graphs, the scale size is often rational not logical, i.e., size of pre-scaled paper, emphasis of characteristics etc. In the absence of any contrary indication, a 1 - 1 scale is the *only* logical choice.

I should have thought that the multiplicity of 8 second echoes ('barrier' or not) would arouse scientific interest in terms of natural causes alone. Two Lagrange points of the Earth are sited at distances roughly corresponding to 8 second echoes – and echoes with this time delay have been heard and noted since 1928. Here is a phenomenon looking (or calling!) for an explanation.

The statement regarding the proper motion of Arcturus can indeed be safely ignored, for taken to a logical conclusion it negates the value of a Planetarium which depicts star positions at any epoch – all deduced from measurements of proper motion!

PS numbers with 3 second delays prior to the sequence are only meaningful in Lunan's hypothesis as base line references. Physicians are not usually interested in normal heart beats or body temperature – only the abnormal provides information. Although surprised, Störmer and Hals were fortunately alert to the change (and new information) and recorded it. This was probably the key event which held the interest of Störmer and other investigators.

The 21 echoes quoted by Professor McVittie as being received by van der Pol, were in fact received by Störmer! A careful reading of 'page 878' of *Nature,* Vol. 122 and the 'Polar Aurorae' will confirm this. Störmer noted 48 echoes but van der Pol (and others) only published 21, and Professor McVittie could provide useful assistance to his own assertions (or Lunan's) if he could use his authority in an endeavour to

locate these and any other sequences obtained at that time.

Professor McVittie's last remarks are out of character and can be safely ignored. The investigations mentioned are dealing with the generation and recording of possible LDE's as the primary objective; we are *not* specifically looking for a probe. To do so would be as opposedly closed minded as saying 'the probe *cannot* exist'.

There are several natural good reasons as to possible causes of LDE's, and Professor McVittie is undoubtedly aware of them. We hope to add to the miserly amount of data.

In conclusion, I would say that the papers are as much of an assertion in astronomy as the announcement of pulsars was an assertion in Interstellar Communication!

Doppler Shift of Radio Echoes

Sir, In Mr. Lunan's article on the Epsilon Boötis probe (*Spaceflight,* April 1973) it is stated several times that the long-delayed echoes were at *exactly* the same frequency as the transmitter, i.e., that there was no Doppler shift. But there must have been *some* Doppler shift, due to the Earth's rotation – furthermore, it would vary from place to place on the Earth's surface, depending on the radial velocities of transmitter and receiver(s) relative to the transmission path. No probe, however intelligent, could provide compensation for this, as it would not know where the receiver(s) were.

JOHN R. MILLBURN

Mr. A. T. Lawton replies:

The statement on Doppler shift caused by the Earth's rotation is valid, but the frequencies would be below audibility for the Eindhoven/Oslo experiments.

Rotational speed of Earth at equator = 25,200 miles in 24 hours = 1050 mph or 0.29 mps.

Therefore, equatorial velocity to velocity of light = 0.29 to 186,200 which is 630,000 to 1 or 0.63×10^6 to 1.

Carrier frequency of Eindhoven PCJJ = 9.55 MHz.

Therefore, equatorial Doppler shift $\Delta f = \dfrac{9.55 \times 10^6}{.63 \times 10^6} = 15$ Hz

But Eindhoven is latitude 51.5° (N)

Therefore Eindhoven Doppler shift = 15 x cos 51.5
= 15 x 0.77
= 11.6 Hz, i.e., below audibility.

In 1928 the signals were checked by setting the receivers to oscillate and the echo 'beat' checked with the directly received 'beat' by ear alone.

The above calculations for Δf are based on a carrier frequency of 9.55 MHz. Since the receivers were superhets with 1F frequencies of 500 KHz (or thereabouts) and the beat oscillator was beating with the 1F to produce the audible notes, this Doppler shift would be unchanged.

Consequently, Lunan, who was quoting from the original papers, is correct.

Crawford (Stanford University, California) on the other hand is measuring delayed echo Doppler shifts by checking the *echo directly against a fraction of the transmitted carrier* – and he is using frequency counters – not ears. Crawford has measured shifts of 55-60 Hz below and 100 Hz above the original signals and consider these effects are most likely caused by interacting ionospheric layers, and is probably right.

Long-delayed echoes may have several explanations – and it is highly probable that the echoes received in 1928-29 were not produced by the same mechanism as those received by Crawford.

Long-Delayed TV Signals

Sir, I was very interested by Ducan Lunan's article in the April issue of *Spaceflight.* I was present at Caxton Hall on 29 March when he and Mr.Lawton spoke. I wonder if Messrs. Lunan and Lawton have heard of a case which I recall reading some years ago. I cannot recall the source but the story is this: A TV engineer (in this country, I believe) picked up a picture of a test card which he could not identify, but naturally assumed it was a freak reception of a distant transmitter. However, the test card was eventually identified, and turned out to be that of an American station which had gone off the air some years before! The story went on to speculate about something in space recording TV transmissions and re-broadcasting them afterwards.

RAYMOND WARD

(The case was reported in the magazine Electronics World *in October 1971. At 3.30 p.m. on 4 September 1953, C. W. Bradley of London, England, picked up on his TV set the American call letters KLEE-TV. Later that month, and at various times thereafter, the same letters were observed on TV screens at Atlantic Electronics Ltd., of Lancaster, England. The strange fact (the magazine reported) was that this signal had been sent from Houston, Texas, three years earlier and had never been transmitted again prior to the time it was received in England. In 1950 KLEE-TV became KPRC-TV and no other TV station on this planet has broadcast the call letters KLEE-TV since.*

The question that must be asked is whether some illegal or amateur broadcaster transmitted the call sign. – Ed.).

Delayed Echoes: Natural or Artificial?

Sir, I read D.A.Lunan's excellent article, 'Space Probe From Epsilon Boötis', with great interest. However, there are two points implicit in the account which I feel need further discussion.

(1) One of the objections raised against the space-probe hypothesis is that long delayed echoes are natural phenomena, perhaps generated by radio waves which pass through the Van Allen belts. However, from the information presented in the article, it appears that all the echo delay times are multiples of a unit of time approximately corresponding to the second , e.g. 3 secs., 8, 11, 12,.... Surely if these echoes were due to some natural process, one would expect the whole spectrum of delay times to be represented; e.g. 3. 6, 7. 4, 8. 5, etc., and not just whole seconds?

Indeed, the fact that only delay times having a length that was an exact multiple of some unit of time were transmitted would seem to be the logical way for an intelligent probe to show that the echoes were not natural. This does not exclude the possibility that *some* long delayed echoes are natural in origin.

(2) Mr. Lunan states that in order to interpret Fig. 6 (p.129) it is necessary to work from right to left. The method used

to display the constellation maps, however, is a graph in which echo delay times are represented on the X-axis moving from left to right in ascending order. This raises the question, would a race which apparently reads right to left use graphs which use figures placed left to right? If, in order to rectify this situation,the graph is turned upside-down (leaving the constellations unaffected since-to a space probe,there is no absolute up or down), then Fig. 6 must be 'read' left to right! A paradoxical situation? It would be interesting to see which way graphs are drawn by groups on Earth which write right to left.

ROSS A. EDWARDS

Anthony Lawton replies:

Both of Mr. Edward's points could be the subject of further papers! In the April issue of *Spaceflight*, we briefly discussed natural causes of LDE's. Evidence accumulated during the last 45 years indicates that delay times are grouped in two peaks at 2 - 3 sec. and 6 - 8 sec. respectively. Störmer freely admitted that the timing of his first 11th October sequence was approximate; Van der Pol's timing was more accurate (stopwatches) but unlikely to be better than 0.1 sec.

It is *not* 'a fact that the times *were* exact multiples of some unit'; this is what makes the projected experiments with accurate timing a very interesting proposition. An intelligent probe could certainly decide that a close approximation to 1 second was the smallest time 'bit' with sufficient resolution to produce charts. If any subsequent sequences are obtained with accurately measured *exact* times multiples,then there is strong evidence for a possible probe. We must wait and see (or hear) further results.

There *are* other Earth languages with different bases for letters and numerology. Arabic *letters* are read from right to left, but the *numerals* (in ascending order) are read from left to right.

Chinese *letters* are read vertically from top to bottom whilst the *numerals* are read horizontally right to left.

Graphs plotted accordingly could be interesting but I am a tyro in these fields and would look forward to hearing from others more expert.

Space Motif

Sir, Over the past few weeks I have developed a motif which I believe typifies Man's evolution out into the Universe. It typifies the Society's ultimate aims – from the first steps, to distant galaxies, by ingenuity and technology.

The scenario is seen to be made up of a number of parts combined in such a way as to portray as much as possible whilst minimizing the complexity of the design, *viz:*

The (BIS) Space-plane, representing Man's future technology, heads for distant galaxies, having originated from the familiar constellation of Apollo landing sites. Its trajectory on the way, is modulated by the stars of the H-R diagram, as Man progressively expands his frontiers through the Galaxy discovering new worlds and using Gravity-Thrust to propel him farther afield. The Sun (depicted), which gave birth to Man, has evolutionary end points coincident with the trajectory of Man's voyages.

P. BURTON

Britain from Space

Sir, In a recent issue, a reader suggested that you publish a satellite picture of the UK. The image which was sent to you by the US authorities was not, in my view, one of those which depicts these islands with the greatest clarity. I enclose a much clearer view. It was obtained by the Nimbus 3 meteorological satellite on 6 August 1969, during a rare, *mostly cloudless*, day over the majority of the European continent.

H.J.P.ARNOLD
Assistant to the Managing
Director, Kodak Limited.

Wrong Moon Trip

Sir, John Young dislocated the cable to the heat-flux probe, not Charles Duke as was stated in the review of the film, *Apollo 16 – Nothing so Hidden*, on page 38 of the January issue of *Spaceflight*. Duke was in the process of drilling holes for the probe, a few yards away, when Young ripped the cable from the experiment.

WILLIAM UPTON

With effect from this issue, technical items of correspondence are being transferred to the Society's 'Journal'.

A Selected Reading List

Many of the items listed are available on loan through the Society. Requests should be sent to the Executive Secretary enclosing 25p (minimum postage rate) for each book or report desired. Items are forwarded only on the understanding that the maximum loan period of one month will not be exceeded. This must be strictly adhered to, to avoid inconvenience to other borrowers.

SPACE COMMUNICATIONS

SYSTEMS

Author	*Title*	*Year of Publication*
NASA Reports		
CR-962	Investigation of the Dynamic Characteristics of a V-antenna for the RAE satellite	1968
CR-977	Study and Applications of Retro-directive and Self-adaptive electromagnetic wave phase controls to a Mars Probe	1968
CR-1922	Investigations of High Power problems in Space Shuttle Antenna Design	1972
TN-D-5100	Solar Effects on VHF Communications between a Synchronous Satellite Relay and Earth Ground Stations	1969
TT-F-527	Radio Bridge: 'Earth-Moon-Earth'	1969 (Moscow 1967)
TT-F-642-8	Interplanetary Flight and Communications	1971
ESRO Reports		
SN-72	Telecommunications by Laser using another Laser as a Thermal Waveguide	1967
RAE Technical Report 64006	Communication coverage by Satellite	1964

GROUND STATION EQUIPMENT

ESRO Report		
SP-65	Spacecraft Operations Vol. II: Data Acquisition and Transmission	1971

POSSIBILITIES, AND DETECTION, OF EXTRATERRESTRIAL LIFE

Books		
T. Allen	The Quest: A Report on Extra-terrestrial Life	1965
C. Maxwell Cade	Other Worlds than Ours	1966
V. A. Firsoff	Life Beyond the Earth	1963
K. W. Gatland and D. D. Dempster	The Inhabited Universe	1957
K. Hener	Men of Other Planets	1951
Cpt. D. C. Homes	The Search for Life on Other Worlds	1966
G. Mamikunian. Ed., and M. H. Briggs	Current Aspects of Exobiology	1965
R. Puccetti	Persons	1968
W. Sullivan	We are not alone	1964
G. M. Tovmasyan.Ed.	Extra-terrestrial Civilization (translated from Russian)	1964
L. S. Young	Extra-terrestrial Biology	1966
Reports		
SP-56	Concepts for Detection of extraterrestrial Life	1964
SP-75	An analysis of the extraterrestrial Life Detection Problem	1965
TT-F-488	The Origin & Initial Development of Life	1968

SPACE LAW

Author	*Title*	*Year of Publication*
Books		
M. Seara Vazquez	Cosmic International Law	1965
Colloquium 1	The Law of Outer Space	1965
" 2	as above	
" 3	as above	
Reports		
SP-44	Conference on the Law of Space and of Satellite Communications	1964
U.S. Senate Committee Report	Legal Problems of Space Exploration (A Symposium)	1961
U.S. Senate Committe Report	Space Law (A Symposium)	1958
Current Legal Problems Report	Communications Satellites	1971

HISTORY OF ASTRONAUTICS

CLASSIC WORKS

Books		
W. von Braun	Das Mars Projekt (Studie einer interplanetarischen Expedition)	1952
P. E. Cleator	Rockets through Space or the Dawn of Interplanetary Travel	1936
Otto Willi Gail	Physik der Weltraumfahrt	1948
Otto Willi Gail	Hans Herdt's Mondfahrt	1928
R. A. Goddard	Rocket Development Diary	1948
W. Hohmann	Die Erreichbarkeit der Himmelskorper	1925
W. Ley and W. von Braun	The Exploration of Mars	1956
H. Oberth	Man into Space	1957
Chas. G. Philp	Stratosphere and Rocket Flight (Astronautics)	1937
R.Richard-Foy	Voyages Interplanetaires et Energie Astronutique	1954
Max Valier	Raketenfahrt	1930
Reports		
TT-F-223	Rocket Flight Engineering by Eugen Sänger (original 1933)	1965
TT-F-236	Collected Works of K.E. Tsiolkovskiy Vol. 1: Aerodynamics	1965
TT-F-237	As above: Vol. 2: Reactive Flying Machines	1965
TT-F-243	Works on Rocket Technology by K. E. Tsiolkovskiy	1965
TT-F-544	Transactions of the first lectures dedicated to the development of the scientific heritage of K. E. Tsiolkovskiy	1970
TT-F-622	Ways to Spaceflight by Hermann Oberth	1972

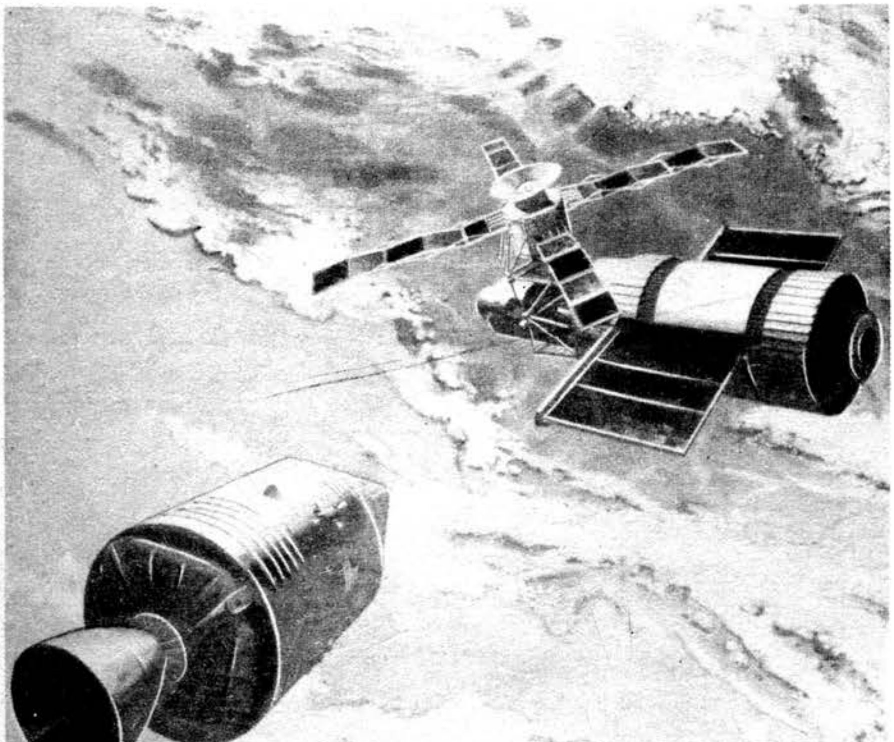
BIBLIOGRAPHIES

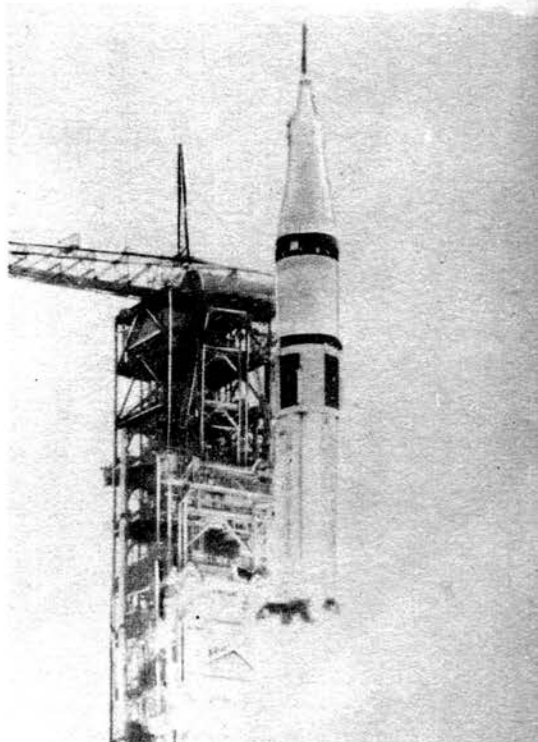
Hughes Research Report 439	Bibliography of Interstellar Flight	1971
Comsat Labs.	Catalogue of Technical papers	1970
NASA HHR-29	History of Aeronautics and Astronautics: A preliminary bibliography	1968
H. H. Koelle and H. J. Kaeppeler	Literature-Index of Astronautics	1954
M. Nicolson	Voyages to the Moon	1948

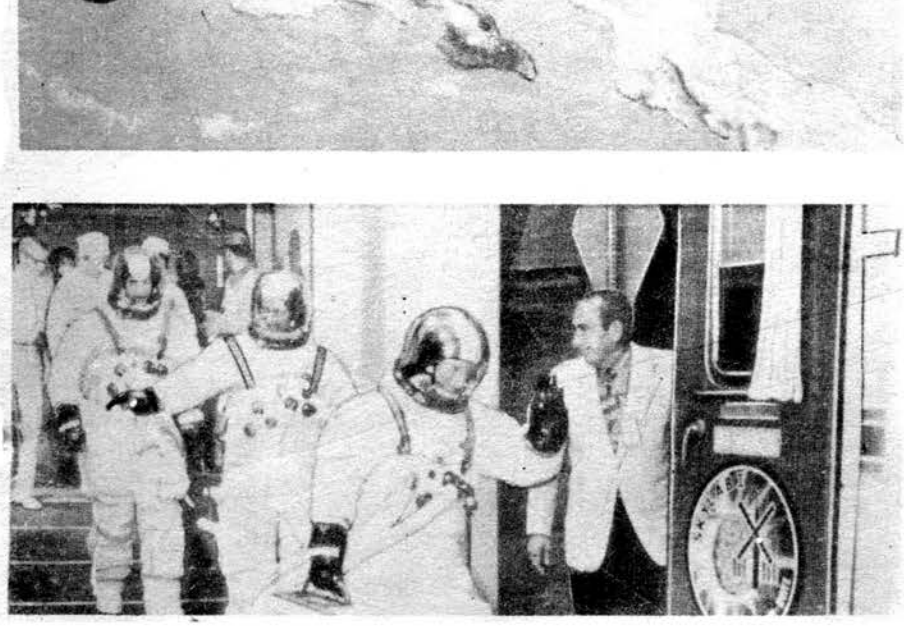
SPACEFLIGHT

88905 КОСМИЧЕСКИЕ ПОЛЕТЫ № T-8
(спейсфлайт)
По подписке 1973 г.

Volume 15 No. 8 August 1973







Published by The British Interplanetary Socie

Editor:
Kenneth W. Gatland, FRAS, FBIS

Assistant Editor:
L. J. Carter, ACIS, FBIS

T 1

SPACEFLIGHT

A Publication of The British Interplanetary Society

VOLUME 15 NO 8 AUGUST 1973 *Published 15 July 1973*

CONTENTS

COVER

SKYLAB IS SAVED. A courageous salvage operation performed by Charles Conrad, Joseph Kerwin and Paul Weitz not only saved the £1,000 million Skylab project but proved beyond question the value of man in space. No better demonstration could have been made before Congress and the world of the need for the re-usable space shuttle to achieve the routine repair and maintenance of costly orbiting hardware. *Top Left,* how the astronauts should have found Skylab with both solar panels deployed. Instead, one solar 'wing' had been torn away with the meteoroid shield during launching and the other was jammed almost shut by torn metal. First a sunshade erected through one of Skylab's scientific airlocks cooled the station; then a spacewalk by Conrad and Kerwin deployed the remaining solar 'wing'. *Below,* the astronaut repair team leaves for the launch pad at Kennedy Space Center on 25 May and, *top right,* blasts off in the nose of Saturn IB.

National Aeronautics and Space Administration

MILESTONES

May

15 India launches nationally-developed sounding rocket prototype of 10 in. diameter, with 5,950 lb. thrust solid-fuel first stage and 1,320 lb. thrust liquid-fuel second stage, from Sriharikota launch centre.

21 French space agency launches Diamant B from Kourou, French Guiana, with twin satellites D-5A and D-5B (Pollux and Castor) but fails to achieve orbit. Third stage did not ignite.

25 First Skylab astronaut team, Charles Conrad, Dr. Joseph Kerwin and Paul Weitz, are launched from Kennedy Space Center by Saturn IB at 1400 hrs. BST carrying three types of improvised heat shields in attempt to salvage Skylab space station. Rendezvous with Skylab is achieved after 7½ hrs, followed by TV inspection of damage. Confirmed that one solar panel had torn away with meteoroid shield. Hour-long attempt by space-suited Weitz standing in Apollo hatchway fails to release remaining solar panel.

26 Astronauts hard-dock with Skylab at 0453 BST at seventh attempt after solving problem with catch actuator switches. After sleep period, they enter overheated Skylab workshop without spacesuits but wearing face masks in case toxic gases had leaked from station's internal insulation when temperatures reach 120°F. Astronauts deploy 22 x 24 ft. parasol-type heat shield from scientific airlock in side of workshop.

29 Skylab astronauts use Apollo Telescope Mount for first time to obtain solar spectra.

30 First full day of experiments aboard Skylab includes solar studies and Earth resources observations. Second of 18 chemical storage batteries fail (first was lost during launch).

June

4 Charles (Pete) Conrad exceeds James Lovell's 715 hr. 5 min. world record for longest time spent by a man in space in multiple space missions.

4 *Novosti* reports that Lunokhod 2 has completed its research programme on the Sea of Serenity, having covered 37 km (23 miles) in 5 lunar days, 3½ times the distance travelled by Lunokhod 1.

6 Skylab astronauts break US duration record for a single manned space flight set by Gemini 7 crew Frank Borman and James Lovell at 330 hr. 35 min.

7 Charles Conrad and Joseph Kerwin spacewalk from Skylab airlock module at 1640 hrs. BST to free jammed solar panel on orbital workshop. After 90 min., Conrad reports: 'We've got the wing out and locked'. See also page 287.

11 Second Skylab crew vehicle, Saturn IB and Apollo CSM, is rolled out at Kennedy Space Center for launch 'no earlier than 27 July'. Capt. Alan Bean, Dr. Owen Garriott and Major Jack Lousma to spend up to 56 days in orbit.

15 Explorer 49, launched from Kennedy Space Center, on 10 June, enters lunar orbit to record deep space radio signals. The craft is equipped with a 750 ft. antenna on each side.

В журнале не печатается ряд страниц.

T 2

TECHNOLOGICAL TRENDS IN COMMERCIAL SATELLITE COMMUNICATIONS

By B. I. Edelson,* Ph.D., FBIS., and R. W. Rostron,* Ph.D.,

Introduction

In the last decade, striking progress was made in commercial satellite communications – technologically, operationally, and financially. The Communications Satellite Corporation (COMSAT) was created in 1963, and the International Telecommunications Satellite Consortium (INTELSAT) in 1964. A system for satellite communications was started in 1965 and became global in 1969. Today, the INTELSAT membership is 83 nations. Eighty earth stations are in operation in 50 countries, and almost 4000 telephone circuits are in full-time use on a worldwide basis.

All of this was reviewed in the December 1972 issue of *Spaceflight* [1]. The present article starts where the last ended, with present operational technology, and then describes current developments and projects technology likely to be employed in the INTELSAT system and other commercial satellite communications systems through this decade and into the 1980's.

Present System

The present INTELSAT network includes four operational Intelsat 4 satellites in the geosynchronous orbit. Two of these satellites are over the Atlantic Ocean region, one is over the Pacific Ocean region, and one is over the Indian Ocean region. The Intelsat 4 spacecraft is cylindrical with a diameter of 2.44 metres. It is 5.34 metres high and weighs about 720 kg in synchronous equatorial orbit [2].

The spacecraft is a dual-spin vehicle in which an outer drum carrying solar cells is spinning while an inner despun platform is utilized to carry the electronics. The antennae are mechanically attached to the despun platform so that they continually point at Earth. Gyroscopic stiffness is provided by the spinning outer drum. Nutation dampers mounted on the despun platform eliminate any potential instabilities arising from unfavourable moment-of-intertia ratios of the system. The attitude accuracy is about 0.25°.

The spacecraft power requirement, including the requirements of the communications subsystem, batteries, and housekeeping, is about 470 watts. Prime power is provided by the cylindrical solar panels, which contain over 45,000 fully shielded silicon solar cells. During solar eclipses, power is provided by rechargeable nickel-cadium batteries.

Intelsat 4 is the first commercial communications satellite to be bandwidth-limited. The communications system is channelised into twelve 36-MHz-bandwidth transponders. All channels receive from a global-beam antenna. Both global- and spot-beam transmit antennae, providing about 22.5- and 34-dBW e.i.r.p., respectively [3], are available.

The satellites receive at 6 GHz and transmit at 4 GHz. Their total capacity may vary from 1500 to 4500 telephone circuits according to traffic distribution, modulation and access technique, and use of spot or global beams. The actual usable capacity of Intelsat 4 satellites in the Atlantic region is about 3800 telephone circuits plus TV and special service.

Earth stations in the INTELSAT system generally employ parabolic antennae 25-32 metres in diameter with centre feeds and subreflectors. The standard receive sensitivity (gain-to-noise-temperature ratio, G/T) exceeds 40.7 dB/°K. Most Earth stations use cryogenically cooled preamplifiers with noise temperatures in the 20°K-30°K range. The high-power transmitters utilize TWTs (or occasionally Klystrons) to provide power outputs of about 5 kW. The modulation and access technique generally employed is FM/FDMA, that is, frequency modulation with multiple carriers accessing the satellite in a frequency-division mode.

The INTELSAT system is currently providing full-time international telephone, telex, telegraph and data service, part-time TV service, and some occasional and emergency service of all types.

* *COMSAT Laboratories, Communications Satellite Corporation, Clarksburg, Maryland, U.S.A.*

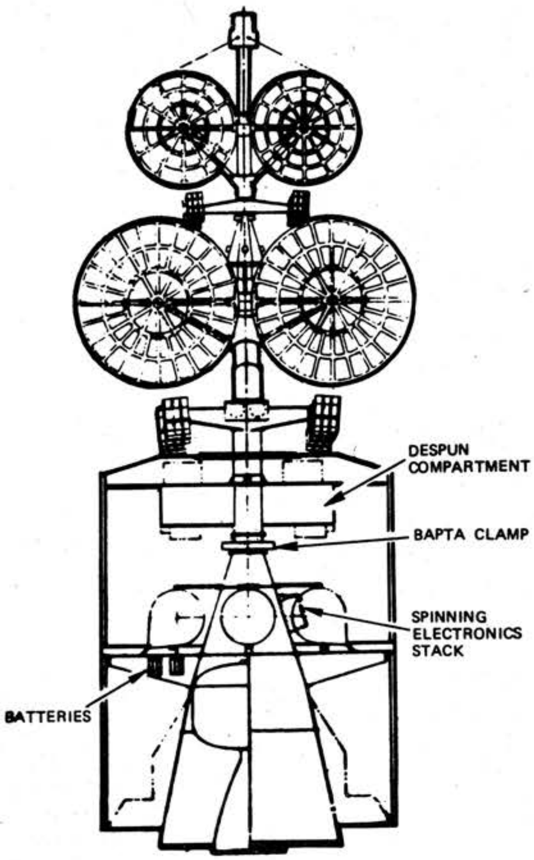


Fig. 1. Intelsat 4-A.

Intelsat 4-A

Extended capacity satellites to be known as Intelsat 4-A have recently been defined. They are intended for initial use in the Atlantic region to meet a higher level of traffic requirements. Each satellite has a usable capacity of approximately 7000 telephone circuits plus TV.

Intelsat 4-A satellites will be the first to incorporate a frequency reuse technique, in this case through spatial separation. The spacecraft body will be very similar to Intelsat 4, but will include a modified communications subsystem and advanced antenna array. The satellite will have four transponders connected to global-beam receive and transit antennae, as in Intelsat 4, and 16 additional transponders, which may be connected to either eastern or western receive or transmit antennae. The satellite is shown in Fig. 1. It will utilise the 6-GHz receive and 4-GHz transmit bands utilised by all previous Intelsat 4 satellites. However, its antenna pattern will allow simultaneous use of the same portion of the spectrum in two separated areas; e.g. in the Atlantic region, one shaped

beam will cover Europe and Africa and the other will cover North and South America.

Intelsat 4-A is only one step in the direction of improved communications capability. A much larger capacity will be required for an Intelsat 5 satellite late in this decade (about 1978). The Intelsat 5 system will be defined in 1973.

Communications Technology Trends

To meet growth requirements in the INTELSAT system and to accommodate expected levels of service in the US domestic and other systems, higher capacity satellites will be required. By the end of this decade, it will be technically feasible to meet a probable capacity requirement of 25.000 to 50,000 circuits.

Satellite capacity is increased by increasing either power or bandwidth. Although power can be increased by a factor of 2 or 3 in satellites in the same weight class, the bandwidth objective is easier to realise, since improvement factors of 10 or more are possible.

Spectrum Utilization

There are three methods of effectively adding bandwidth: use of new frequency bands, reuse of the existing frequency bands by polarization discrimination, and reuse of the existing bands through spatial separation. All three methods are expected to be used in US and other domestic systems, and in the INTELSAT system in the next decade.

The opening of portions of the RF spectrum above 10 GHz offers a direct capacity increase. New frequency allocations for satellite communications were agreed upon at the ITU World Administrative Radio Conference held in 1971. The new frequency bands of greatest interest to commercial

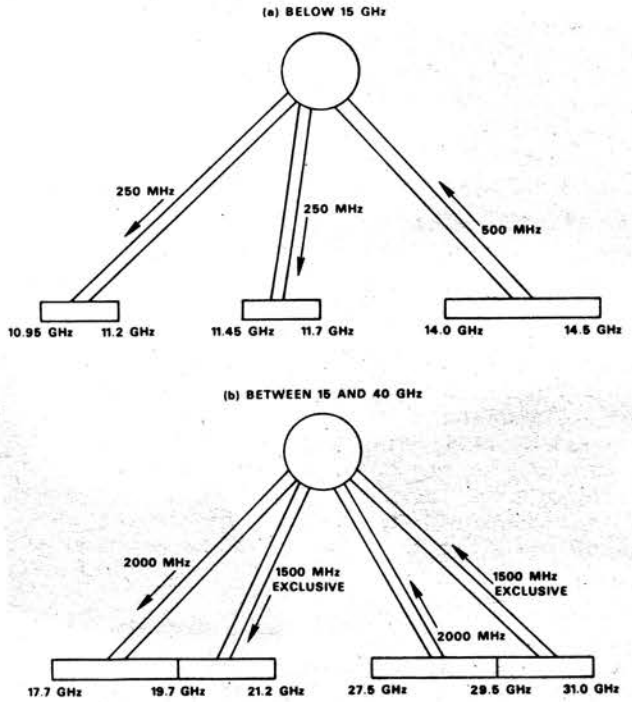


Fig. 2. New frequency bands of interest to commercial communications satellites.

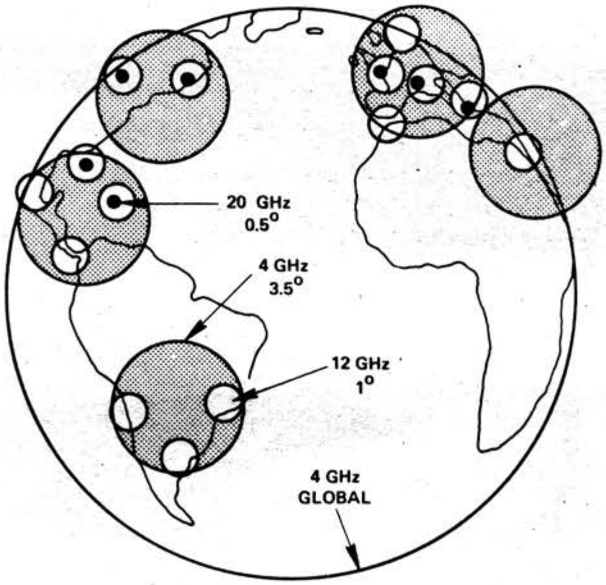


Fig. 3. Possible composite beam pattern for future satellites.

communications satellites are shown in Fig. 2. The 14/12-GHz bands provide 500 MHz in both the up-link and the down-link. The down-link band is split into separate 250-MHz segments, however. This will probably complicate future spacecraft. In addition, the requirement for multiple frequency translation in the satellite will represent an additional burden.

The second pair of frequency bands of interest to commercial communications satellites are 17.7 to 21.2 GHz for the down-link and 27.5 to 31.0 GHz for the up-link. These frequency allotments represent a potential bandwidth of 3500 MHz in both the up-link and down-link. The technology of all these bands is under development, but since propagation conditions are significantly better in the 14/12-GHz bands, they will probably be used before the higher bands.

Reuse of the available frequencies, particularly at 4 and 6 GHz, through polarization discrimination can effectively double the available bandwidth. At 4 and 6 GHz, the technology has sufficiently advanced to make this approach available and practical in the mid-1970's. The satellite antenna will be a critical element. It must have low sidelobe envelopes and a high degree of polarization isolation (about 25 dB) to reduce interference among the signals sharing the spectrum.

Establishing links among several Earth stations through spatially separated satellite beams is the third method of reusing the available frequency bands. In the future, this concept, to be employed for a single reuse in Intelsat 4-A, will make it possible to use the same frequency band 4, 8, or even more times. Spot beams 3° to 5° wide can be used at 4 and 6 GHz and, in addition, numerous very narrow beams (with beamwidths of 1° to 2°) can be used at the higher frequencies. Matching traffic requirements with available bandwidth in beams of different sizes can result in a composite beam pattern of the type illustrated in Fig. 3.

Satellite Switching

To provide the required connectivity among various beams, a switching technique may be used in the satellite. Beams may be interconnected through a time-division switching matrix

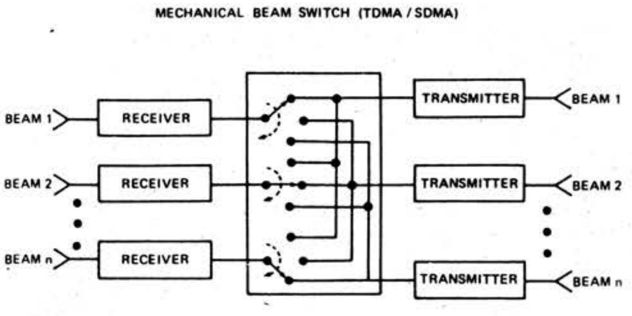


Fig. 4. Satellite-switched TDMA scheme.

on the satellite, as illustrated schematically in Fig. 4. Each broadband receiver, which is connected to an up-link beam at 6, 14, or 30 GHz, is fed from the switch. Earth stations transmit in a burst mode. The satellite switch, which is controlled by the time-division multiple-access (TDMA) sequence, connects each receiver in the satellite to the appropriate transmitter.

Within a given frame, time slots are allocated to Earth stations for transmission to other Earth stations. During the first interval, each Earth station is connected back to itself via the satellite for synchronization and traffic distribution within its own satellite antenna beam. Thereafter, each Earth station sequentially transmits to other Earth stations using a burst mode and an algorithm which precludes mutual interference. Because each transmitter operates essentially in the single-carrier mode at saturation, and because the weight and power requirements of the switch are small, the satellite-switched TDMA system is highly efficient. This system also offers a high degree of flexibility, since the allocation of time slots can be changed quickly to adapt to network requirements.

Connectivity among various antenna beams can also be accomplished through a frequency-division multiple-access (FDMA) technique that involves routing signals through the satellite by means of a passive filter system. Each Earth station generates several carriers which are separated in frequency. These carriers are received by the satellite and routed to the correct down-link beam by the channel-dropping filter. It should be noted that the FDMA system is not as efficient as the TDMA system because of the loss in TWT efficiency. Also the, weight and power requirements imposed on the spacecraft are greater for FDMA.

To accommodate these advanced communications techniques, some technical improvements in the spacecraft will also be necessary. Some of these are discussed in the following section.

Spacecraft Technology Trends

Satellite Stabilization

So far all satellites Intelsat 1 to Intelsat 4-A are spin stabilized. Advantages of this technique are its simplicity and the technical community's very high degree of confidence in its

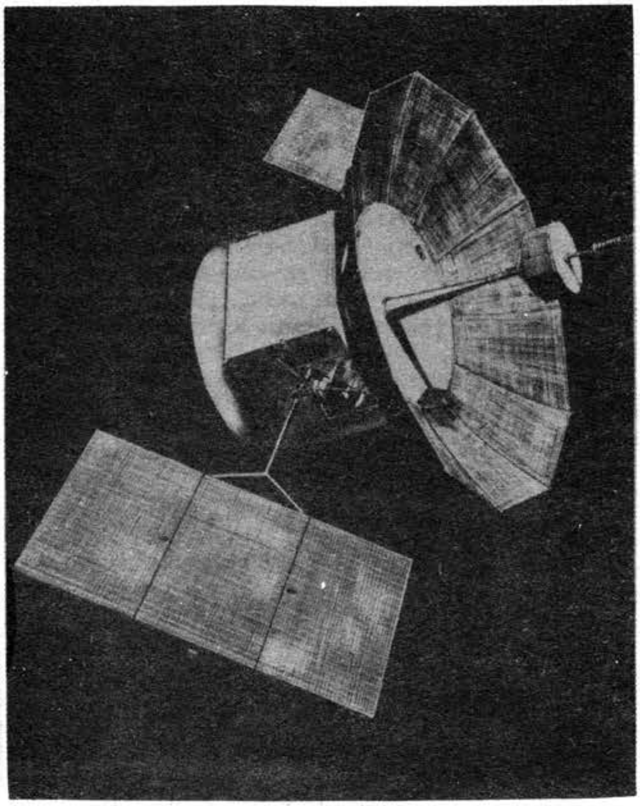


Fig. 5. FLEETSAT communications Satellite.

applicability to satellite communications. However, body-stabilized designs* are also attractive for geostationary communications satellites. Particular advantages of these designs are:

(a) high pointing accuracy for spot beams
(b) ability to support large complex appendages, such as multiple communications antennae and oriented extendable solar arrays
(c) flexibility to adapt to changing requirements, communications packages, and appendages ('bus' concept)

These advantages make it likely that many future communications satellites will be body stabilized [4]. Several experimental versions, the NASA ATS-F, the Canadian CTS, the U.K. GTS, and the Franco-German Symphony, will prove the feasibility of this design.

The next generation US military satellite, known as FLEETSATCOM and shown in Fig. 5, will be the first operational body-stabilized communications satellite. In all cases, prime power can be increased over that provided by spin-stabilized designs of the same weight. Interestingly, users of both the frequencies above and below the present 6/4-GHz band will benefit from body stabilization; users of the lower

---

* *Sometimes with a degree of confusion referred to as '3-axis stabilized'. Both body-spinning and body-stabilized designs use the gyroscopic principle. In the former, the large body of the satellite spins slowly; in the latter, the body remains oriented while internal momentum wheel (s) spin at high speed.*

Table 1. Comparison of INTELSAT 4 and One Configuration of a Future Communications Satellite

Characteristic	INTELSAT 4	1980 Satellite
Capacity (usable circuits*)	3,800	25,000
Frequencies	6/4 GHz	6/4 14/11 GHz
Modulation/Access	FM-FDMA	PSK-SS/TDMA
Weight	720 kg	340 kg
Prime Power	Silicon Cells, Spinning Array, 500 W	High Efficiency Cells, Deployable Oriented Array, 750 W
Energy Storage	Ni-Cd Batteries	Gas Electrode Cells or Batteries
Stabilization	Dual-Spin	Body-Stabilzed
Position Keeping	Hydrazine	Hydrazine Plus Ion Engine
Lifetime	7 years	7 years
Investment/Circuit/Year	$1000	$100

* 1 circuit = 2 channels.

frequencies will benefit from the ease in mounting large antennae, and users of the higher frequencies will benefit from the more accurate pointing capability available.

Electric Power

Prime power for future communications satellites may be supplied by new high-efficiency, radiation-resistant solar cells [5] mounted on a lightweight, deployable, sun-oriented structure. These new solar cells are capable of providing 35% more power than present technology cells. This increase in efficiency has resulted from better utilization of the violet portion of the solar spectrum, as well as from improved diode characteristics. Energy storage now provided by nickel-cadmium batteries may be provided in future satellites by lightweight, rechargable, gas/metal electrode fuel cells. For example, a new nickel-hydrogen battery being developed under INTELSAT sponsorship will result in significant improvement in both energy density and cyclic life [6].

Propulsion

Electrostatic ion thrusters are attractive for use on future commercial communications satellites for two reasons: their high propellent exhaust velocity results in substantial reduction of the mass of the propulsion system, and their low thrust greatly reduces the magnitude of disturbance torques caused by thrust misalignment. All of the onboard propulsion tasks can be performed with electric propulsion, but the first applications will probably concentrate on the major propulsion tasks, i.e. north-south station-keeping and repositioning, since weight savings are most apparent here [7]. A recent concept, that of battery-powered electric propulsion with nickel-hydrogen batteries [8], makes it possible to perform both these propulsion tasks, and possibly initial acquisition as well, with a single-thruster system. Weight savings in the range of 15-20% of the entire satellite mass can be expected with these combined technologies.

Technology Comparisons

The effect of several of these new technologies on satellite design is illustrated in Fig. 6. In this figure, the number of usable channels is plotted as a function of spacecraft weight for satellites incorporating various combinations of new technologies. The appropriate launch vehicle class is also shown as a function of spacecraft weight. Since the launch vehicle cost represents a significant percentage of the overall space segment cost, it is important to ensure that the full payload capability of a launch vehicle is utilized.

Certain anticipated characteristics of a 1980 communications satellite may be compared with Intelsat 4 characteristics to dramatise the potential of new technologies [9]. This comparison is shown in Table 1.

Earth Station Technology Trends

Several trends are evident in Earth station technology. These include high reliability, wide bandwidth, high capacity, low cost, unattended operation, and smaller size [10]. Not all of these are obtainable in the same Earth station, of course.

Large Earth stations will continue to operate in the 6/4-GHz bands for international and domestic point-to-point services. Generally they will provide multiple service to terrestrial distribution points. They will have antenna apertures approximately 25-32 metres in diameter and will generally use cooled parametric amplifiers with noise temperatures of 30°-50°K. Large Earth stations will have power outputs up to 10 kW. Polarizers and orthomode transducers are currently being developed for use in these stations to provide a high level of polarization purity. In the INTELSAT system, circular polarization will continue to be used, but new domestic systems are most likely to employ linear-polarization to obtain better discimination.

Smaller Earth stations with apertures of 10 metres or less will be employed for the introduction of frequencies in the 14/11- and 30/20-GHz bands [11]. Some spatial diversity, i.e. two Earth stations separated by 16 to 31 km, will be required, particularly for use of the 30/20-GHz band, to provide reliable communications during periods of heavy precipitation.

Even at 6/4-GHz, the use of small terminals appears attractive for domestic service and regional networks and special

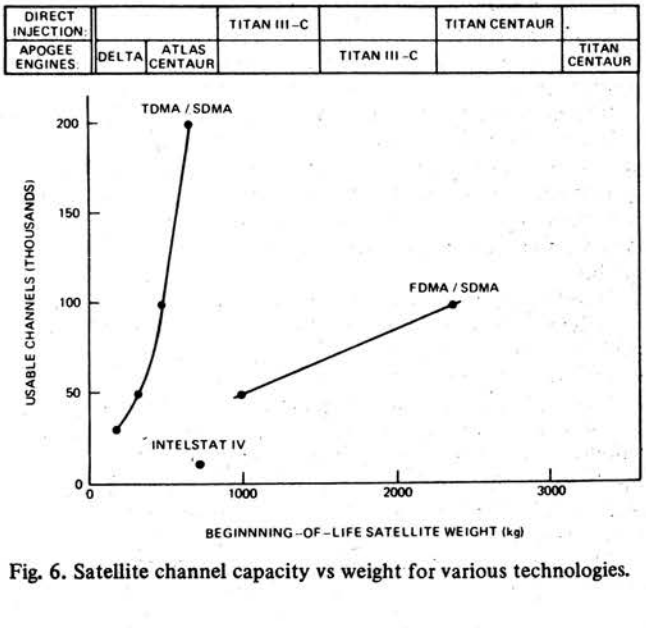


Fig. 6. Satellite channel capacity vs weight for various technologies.

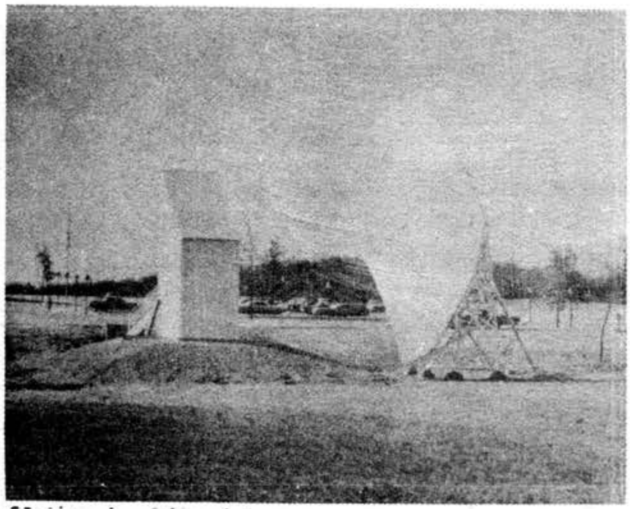


Fig. 7. Prototype Multiple-beam torus antenna.

services in the international system. Small Earth stations can provide more direct service to users such as communities, islands, or individual industrial plants, as opposed to countries or large geographic areas. In addition, small stations can be inexpensive and reliable and may be unattended in the future. They may be located within cities, on building roofs, or on sea-based platforms.

Although small terminals cost less to build, they may use satellite capacity less efficiently. Tradeoffs between satellite use and Earth station costs can be readily performed to show the optimum size for a given set of requirements. For domestic service, the typical total cost of providing service through a 4.5-m station can be less than half that of a standard station on a per-circuit-year basis.

A very interesting new development applicable to different frequency bands and antenna sizes is the multiple-beam torus design [12]. This is a fixed-reflector-type antenna with a movable feed system. It is capable of forming many independent beams, each directed toward a satellite in a synchronous orbit around the Earth. This feature allows a single Earth station antenna to act as a terminal for many satellite transmission links.

The multiple-beam torus antenna is economical and requires minimum maintenance because of its simple structural design and its fixed reflector, which obviates a servo control system and costly bearings and drives. Its beam-steering capability is unique. Specifically, it uses a simple, low-intertia-type feed movement following the daily motion of an orbiting satellite.

Interference affects the operation of the torus antenna considerably less than that of other antennae because the torus reflector is illuminated by offset feeding, thus eliminating aperture blockage.

The feed system used with this design is intended to satisfy a variety of requirements, such as wide bandwidth, high power-handling capability, low insertion loss, and efficient illumination of the reflector. It is also capable of generating any two orthogonal polarizations and obtaining a high degree of isolation between them.

The important electrical characteristics of the torus design, including gain, sidelobe levels, low-noise temperature, polarization quality, bandwidth, and multiple-beam-forming capability, have been experimentally demonstrated on an engineering test model. A prototype antenna of this type with equivalent 9-metre aperture is shown in Fig. 7.

Transmission Systems

Along with advanced satellite and Earth station technologies, new transmission techniques are emerging to provide more efficient utilization of the available frequency bands. As in other areas of electrical communications, digital techniques offer several distinct advantages over analog techniques in satellite communications:

(a) efficiency in bandwidth utilization and power conversion;
(b) flexibility;
(c) ruggedness;
(d) signal processing;
(e) error control (channel encoding); and
(f) message compression (source encoding).

SPADE is a digital multiple-access demand-assigment system which has been authorised by INTELSAT for operational use and is now being introduced into service in the INTELSAT system [13]. SPADE uses pulse coding combined with phase-shift-keyed modulation and frequency-division multiple-access techniques. Satellite bandwidth and power are used more efficiently because the satellite transponder capacity is assigned to circuits for use on a demand basis. SPADE is particularly promising for small countries and other users on lightly loaded links. Techniques are now being developed which will allow use of the SPADE network for telegraphy and data transmission, small Earth stations with all-digital transmission, and single-channel multi-destination traffic.

Another major development in transmission systems is TDMA,* which allows several Earth stations to use the same frequency band, each station transmitting sequentially in short bursts [14]. Thus, each user has access to the total available transponder power and bandwidth during periodic time intervals. TDMA allows satellite travelling wave tube amplifiers to operate at their maximum power levels and reduces the effects of interference and intermodulation noise. Thus, satellite capacity may be significantly increased (by a factor of 2). In 1970, three prototype INTELSAT TDMA terminals were successfully tested with Earth stations in Hawaii, Japan, and Australia and an Intelsat 3 satellite.

An all-digital system is under development for the transmission of colour TV [15]. This system is intended to make possible the transmission of two colour TV channels and several voice channels through a single Intelsat 4 satellite transponder without loss of information content or picture quality. Field tests of COMSAT's version (DITEC) are being conducted over satellite links in 1973.

Summary and Conclusions

Commercial satellite communication technology is advancing rapidly over a broad front in spacecraft, Earth stations, and transmission systems. These advances are paced by increasing traffic and by requirements for new services. As domestic and international telephone, telegraph, TV, high-speed data, facsimile, library, and educational services are

* *Time-division multiple access.*

required, there will be an increasing demand for higher and higher capacities and performance. The technology will thus tend toward those techniques that make possible the capacity required at a low cost per channel year.

Important trends in satellites will be those involving body stabilization and lightweight propulsion and energy systems. In this decade, satellites will transmit and receive multiple beams in several frequency bands.

Time-division switching between beams will come into use somewhat later. Earth stations will become more reliable and provide higher capacities. Those involved in domestic service are likely to be much less expensive, smaller, and unattended. The multiple-beam torus design will be very attractive for use with more than one satellite at a time. Digital transmission systems are a definite trend of the future for many types of services.

Acknowledgements

The assistance of several members of the staff of COMSAT Laboratories is appreciated. Although this article draws upon work performed in INTELSAT and COMSAT studies, the predictions of future technology trends represent the views of the authors and are not necessarily those of either organisation.

REFERENCES

1. B. I. Edelson, 'Progress in Commercial Satellite Communications', *Spaceflight*, **14**, 12, pp. 468-474, 1972.
2. E. T. Jilg, *et al.*, 'The INTELSAT IV Spacecraft', *COMSAT Technical Review*, **2**, 2, pp. 271-389, 1972.
3. P. L. Bargellini, *et al.*, 'The INTELSAT IV Communications System', *COMSAT Technical Review*, **2**, 2, pp. 437-572, 1972.
4. W. L. Pritchard and P. L. Bargellini, 'Trends in Technology for Communications Satellites', *Astronautics and Aeronautics*, pp. 36-42, Apr. 1972.
5. J. Lindmayer and J. Allison, 'The Violet Cell: An Improved Silicon Solar Cell', *COMSAT Technical Review*, **3**, 1, 1973.
6. J. F. Stockel, *et al.*, 'A Nickel-Hydrogen Secondary Cell for Synchronous Orbit Application', 7th IECEC, 25 Sep. 1972.
7. B. A. Free, 'Chemical and Electric Propulsion Tradeoffs for Communications Satellites', *COMSAT Technical Review*, **2**, 1, pp. 123-145, 1972.
8. B. A. Free and J. D. Dunlop, 'Battery Powered Electric Propulsion for North-South Stationkeeping', *COMSAT Technical Review*, **3**, 1, 1973.
9. J. D. Kiesling, *et al.*, 'A Technique for Modelling Communications Satellites', *COMSAT Technical Review*, **2**, 1, pp. 73-103, 1972.
10. B. I. Edelson, 'Satellite Access: Small Earth Terminals', presented at AIAA 9th Annual Meeting and Technical Display, Washington, D.C., 9 Jan. 1973.
11. J. L. Levatich and J. L. King, 'ATS-F COMSAT Millimeter Wave Propagation Experiment', presented at 1972 IEEE NTC, Houston, Texas, 5 Dec. 1972.
12. G. Hyde, W. Korvin, and R. Price, 'A Fixed Multiple Beam Toroidal Reflector Antenna Operating at Frequencies Above 12 GHz', presented at the IEEE International Conference on Communications, Montreal, Canada, 14-16 Jun. 1971.
13. B. I. Edelson and A. M. Werth, 'SPADE System Progress and Application', *COMSAT Technical Review*, **2**, 1, pp. 221-242, 1972.
14. J. G. Puente, W. Schmidt, and A. Werth, 'Multiple Access Techniques for Commercial Satellites', *Proceedings of the IEEE*, **59**, 2, 1971.
15. L. Golding and P. Kaul, 'DITEC – A Digital TV Communications System for Satellite Links', presented at the Second International Digital Satellite Communications Conference, Paris, France, 28-30 Nov. 1972.

SPACE REPORT

A regular monthly review of Space Events and Technical Trends

NEW APPROACH TO LUNAR STUDIES

NASA has established a new programme for the analysis and interpretation of the vast amount of information returned from the Moon over the past 10 years. Under the new approach, known as the Lunar Data Analysis and Synthesis Programme, scientists will be encouraged to propose investigations which draw on a variety of lunar data and which cut across a number of scientific disciplines.

Through the synthesis of lunar information obtained from many scientific fields, NASA hopes to more readily build a detailed picture of the origin and history of the Moon, and its present characteristics. Such knowledge would carry implications for other planets in the Solar System, including Earth, which are all believed to have been formed about the same time. The Lunar Synthesis Programme will also provide the basis for the planning of future missions to the Moon and other space exploration. It also calls for broad dissemination of new knowledge to the public, as well as to the scientist, through books, films, TV and lectures.

Until now, most lunar investigators have concentrated on a single experiment or group of experiments in their own particular field. Under the new programme, emphasis will be on studies which attempt to blend information from several sources – Apollo experiments and photography, lunar mapping, Moon samples, and data from the early unmanned spacecraft which have orbited or landed on the Moon, as well as from theoretical studies and Earth-based observations.

Since 1963, three Rangers, an Explorer, five Surveyors, Five Lunar Orbiters and nine Apollo lunar missions have acquired a vast amount of new scientific data, which have made possible a more detailed picture of lunar history. We know now that the Moon is a complex body whose origin dates back to the beginning of the Solar System; that its formation and evolution can be related to more general planetary processes, and that a record of events in the history of our Sun and our Galaxy can be found on the lunar surface.

'Encouraging and impressive as these results are, they

represent only a start on the analysis and assimilation of data', according to John E. Naugle, Associate Administrator for Space Science. 'New information will continue to be received from the Apollo Lunar Surface Experiment Packages (ALSEPs), the Lunar Laser Ranging Experiment and the orbiting Apollo 15 subsatellite. During the next decade, our efforts must be devoted to the systematic analysis and interpretation of the growing storehouse of data'.

Scientists throughout the world are being invited to propose investigations for the new programme, which will be conducted under NASA's Lunar Programmes Division, headed by William T. O'Bryant, a part of the Office of Space Science.

US scientists should submit two copies of their proposals to the Director, Office of University Affairs, NASA, Code PY, Washington, DC 20546, and 25 copies to Manager, Lunar Data Analysis and Synthesis Programme, Lunar Programmes Division, Office of Space Science, NASA' Code SM, Washington DC 20546. Scientists outside the US must submit proposals through their government sponsoring agency to Office of International Affairs, NASA, Code I, Washington, DC 20546.

DATING THE ORANGE MOON-SOIL

A major clue to the history of the orange soil discovered on the Moon by the Apollo 17 astronauts has been reported by the General Electric Company of the USA's Research and Development Center. By analysing the density of cosmic ray tracks found in the samples, researchers determined that the material lay exposed on the Moon's surface for only 8 to 10 million years, a relatively brief span of time.

This new finding adds another significant fragment of information to the small but slowly accumulating body of data on the strange material. Until the Apollo 17 mission took place, orange soil had never before been seen on the Moon. Under the microscope, the soil turns out to be composed of tiny pieces of reddish-brown glass, and its discovery has generated a large amount of scientific excitement and speculation.

When Geologist-Astronaut Harrison J. Schmitt discovered the orange soil near Shorty crater during the second EVA, he suggested that it might be some of the youngest material ever found on the Moon. This did not turn out to be the case. Scientists at the State University of New York at Stony Brook used a radioactive dating technique to show that the orange soil was actually formed about 3,700 million years ago, and is just as ancient as much of the other material collected by the Apollo astronauts. The GE(USA) research, however, now indicates that the orange soil had a relatively 'young' life on the surface of the Moon, showing that Schmitt was at least partially correct.

From the GE(USA) and Stony Brook work, it is now known that when the orange soil was formed 3,700 million years ago, it was quickly buried within the Moon's surface at a level deep enough to protect it from cosmic rays. Then, from 8 to 10 million years ago, an unknown natural force – most probably a meteoroid impact – churned up the Moon's surface layers, moving the orange soil to the surface. There, it became subject to cosmic ray bombardment, which left tiny invisible 'tracks' in the glass fragments that make up the soil. As a cosmic ray passes through a piece of lunar glass, it creates a trail of damage less than a millionth of an inch wide. To enlarge the track for study, the glass sample can be etched, dissolving the radiation damage and producing cone-shaped holes or tracks.

Cosmic ray bombardment of the Moon is believed to have remained constant over hundreds of millions of years. Most cosmic rays do not penetrate very deeply into the surface of the Moon. Thus, by counting the cosmic ray tracks in a lunar sample, researchers can determine how much time a rock has spent on the lunar surface. The longer the exposure, the more tracks are found.

RADAR 'PICTURES' OF MOON

Scientists have put together the first closeup radar images of the Moon's surface, obtained from the orbiting Apollo 17 spacecraft last December. The radar 'pictures', the initial products of the Apollo lunar sounder experiment, will eventually provide a geologic cross-section of the Moon, detailing subsurface structure to a depth of 1.3 km (0.8 miles).

Scientists and engineers at four organisations developed the experiment and are analysing the data. They are the Jet Propulsion Laboratory, Pasadena, California; the University of Utah, Salt Lake City; the University of Michigan, Ann Arbor; and the Center for Astrogeology, US Geological Survey, Flagstaff, Arizona.

The experiment was designed to provide both imagery and sounding data.

The radar instrument was operated by astronaut Ronald Evans as Apollo 17 circled the Moon at an altitude of about 100 km (62 miles). On the Earth-return flight, Evans recovered cassettes of recorded data from the sounder and other instruments housed in the scientific instrument module during a space walk.

Experience gained in operating the lunar sounder and analysing the radar information will contribute to the design of future instruments for detection of surface or near-surface water on Mars, mapping of major geological features on Mars and Venus, topside sounding of Jupiter and the study of Earth's oceans.

ROCK RINGS OF SATURN

The rings of Saturn appear to be made of solid matter rather than gas, ice crystals or dust, according to Dr. Richard M. Goldstein and George A. Morris Jr., of the Jet Propulsion Laboratory, California. Using the 64-metre (210 ft.) antenna at Goldstone Station on the Mojave Desert, they probed Saturn and its rings a dozen times during December and January with 12.5 cm wavelength 400 kw beams. Bounceback signals indicated that the rings are more likely to consist of rough, jagged surfaces, with solid material one metre (3.3 ft.) in diametre or larger. Dr. Goldstein warned, moreover, that Saturn's rings, encircling the planet from 90,000 – 140,000 km – (57,000 to 85,000 miles) out, 'must be considered an extreme hazard to any spacecraft sent into or near the rings'. NASA plans to send a Mariner spacecraft past Jupiter and Saturn in 1977.

Many space scientists and astronomers believe Saturn's rings are very thin and consist of ice crystals, dust particles or gas, or some combination. But the relatively strong radar echoes contradict some of the old theories, according to

Goldstein. The signals from the rings were five times stronger than Venus would be at that size and distance.

'The planet is not a good radar reflector, but the rings definitely are', he said. 'The ring chunks certainly have to be closely packed, although not too closely because starlight has been seen shining through them. They cannot be much smaller than one metre in size and may be much larger'

The radar signals travelled 1,500 million miles to Saturn and back in 2 hr. 15 min. the longest planetary radar bounce yet attempted, according to the JPL scientists.

Saturn has at least three rings, ranging outward some 140,000 km (85,000 miles). The width of the principal inner ring is estimated at 25,000 km (16,000 miles), and 16,000 km (10,000 miles) for the outer ring. Despite their globe-girdling circumference, the rings appear through telescopes to be perhaps only a kilometre (3,300 ft.) thick. Water ice has been thought to be a principal component of the rings, with temperatures as cold as -308°F.

Saturn itself is about 120,000 kilometres (72,000 miles) in diameter. Its mass is calculated to be 95 times that of Earth. Yet it is believed to be a gaseous body with a density less than water, and a surface gravity approximately that of Earth.

While one report prepared for NASA in 1970 held that flying through Saturn's rings would present 'negligible danger', JPL project planners for the Jupiter and Saturn mission had already decided to observe both planets from a safe distance. Because of Jupiter's strong radiation belts, Mariner '77 will approach no closer than 405,000 km (250,000 miles) to that planet. At Saturn, the closest approach will be 270,000 km (167,000 miles), some 130,000 km (82,000 miles) from the outer ring. Instruments are being designed to give the desired data from these distances.

Mariner '77, scheduled to be launched sometime between 19 August and 17 September 1977, will pass Jupiter in the spring of 1979, and arrive in Saturn's vicinity in the spring of 1981.

ECONOMIC SALYUT

Large Earth satellites orbiting for long periods are one of the most important trends in space techniques for the solution of many scientific and economic problems, according to cosmonaut Maj-Gen. Vladimir Shatalov. Speaking on the eve of Cosmonautics Day (12 April) he said that orbital stations of the Salyut type, manned or unmanned, could yield valuable information for space scientists, carry out valuable experiments for the weather service, geology, sea and air transport, communications, forestry and agricultural and also the protection of Earth's natural environment. They will also be used for testing new developments in space techniques and technology. Eventually, manned spaceships and automatic observatories would be launched from them to other planets.

Shatalov pointed out that the NASA manned orbital station Skylab is similar to Salyut in design and purpose.

SOVIET-INDIAN SPACE CO-OPERATION

A delegation of the USSR Academy of Sciences and scientists of India's Space Research Organisation have completed talks in Bangalore on questions connected with the launching of an Indian Earth satellite. The Soviet delegation was headed by Academician Boris Petrov, chairman of the Council of International Co-operation in the Field of Exploration and Use of Outer Space (Intercosmos), and the Indian side by Professor S. Dhavan, chairman of the Space Research Organisation. In the course of the talks agreement was reached on various technical and organisational matters concerned with the launching.

The joint use of outer space for peaceful purposes is one of the areas of wide co-operation between the USSR and India in the field of science and technology, reports the Novosti Press Agency. The agreement on launching by a Soviet rocket carrier from Soviet territory of an Indian research satellite and technical assistance in its development is a further step in strengthening this co-operation. India's first satellite, designed and manufactured in India, will carry scientific instruments. It weighs 300 kg (660 lb.) and will be placed into a circular orbit with a radius of 600 km (373 miles) by a Soviet rocket from a cosmodrome on Soviet territory in 1974.

Academician Petrov said in a Soviet press interview that the meeting of Soviet and Indian scientists in Bangalore was an important step in the implementation of this project. The basic technical issues were connected with the development of the satellite's design: the orientation system, the memory unit, the system of power supply and thermal control. This part of the on-board service equipment is designed by Indian scientists. The meeting made it possible to co-ordinate further mutual development of the project, and to set up mixed Soviet-Indian groups.

'Young Indian scientists, engineers and technicians', Academician Petrov stressed, 'are people of high skill and good theroretical grounding, which predetermined the success of the joint work in Bangalore'.

In the course of the visit Premier Indira Gandhi received Academician Petrov. Their talk covered questions relating to scientific and technical co-operation between the USSR and India. The scientist said that the experience of joint work with Indian colleagues had re-affirmed confidence in the successful completion of the project and good prospects for friendly co-operation between the two countries.

COUSTEAU AND NASA

Ocean-explorer Captain Jacques Cousteau and NASA worked together during Cousteau's recent Antarctic expedition to see how space-age technology can be used in oceangraphic investigations to define biologically productive ocean regions. The results were encouraging and Cousteau said artificial satellites had opened 'a whole new dimension to ocean resource monitoring'.

Cousteau, aboard his research vessel, the *Calypso*, was in direct contact 5 days a week with Ames Research Center, Mountain View, California, transmitting and receiving information via weather satellites and NASA's Appplications Technology Satellite (ATS-3), managed by the Goddard Space Flight Center.

The *Calypso* operated along the coast of the Antarctic Peninsula. NASA weather and communications equipment were put aboard last Autumn by personnel from Goddard. Afterwards the *Calypso* sailed up the west coast of South America, continuing oceangraphic studies , and ending the cruise at Los Angeles this summer.

The research ship made direct measurements of chlorophyll and temperature readings of the ocean and transmitted these data via ATS to scientists at Ames. John Arveson, of Ames, and Professor Ellen Weaver, of California State University, San Jose, used these measurements to derive correlations with ocean colour and temperature observations from Earth Resources Technology Satellite-1 (ERTS-1), and the Nimbus and NOAA weather satellites.

Too little chlorophyll in the oceans indicates a low food-producing potential. A medium amount is necessary for high productivity. Extremely high chlorophyll content could be a sign of pollution. Both chlorophyll and water temperatures are closely related to amounts of microscopic plants called phytoplankton which are the bottom of the food chain for all fish in the oceans.

In addition to the Ames data, Nimbus 5 microwave radiometer data, received on the *Calypso*, made it possible to delineate sea-ice conditions clearly enough to provide navigation information through the Antarctic ice fields.

NEW ESRO SATELLITES

The Council of the European Space Research Organisation has decided that ESRO should undertake two new scientific satellites:

(a) HELOS (Highly Eccentric Lunar Occultation Satellite), devoted to X-ray astronomy to be launched in 1979; and

(b) the ISEPS (International Sun-Earth Physics Satellites programme) 'Daughter' satellite, one of a pair of which NASA is to develop the 'Mother'. The two satellites are designed to be placed in orbit 'in tandem' by a single launcher in 1977.

The scientific aims of HELOS are the definition of the position, the mapping of the spatial and spectral features and the monitoring of the time variables of X-ray sources. Through these measurements it is expected that HELOS will help answer questions of fundamental importance about the structure of the Universe by means of source counts; about the nature of 'black holes' through the temporal and energy features of compact objects; and about the 'open-close' Universe theory through the mapping of intergalactic material. HELOS is a second generation satellite which will follow several non-ESRO survey X-ray satellites to be launched before 1977.

In the ISEPS programme – an ESRO/NASA co-operative programme – it is intended to use the pair of satellites, which will have carefully controlled separation, to distinguish between spatial and temporal variations. The mission will therefore be especially suited to studies of the numerous boundary regions and discontinuities such as the magnetopause, the bow shock, the neutral sheet in the tail and the wave-shocks and other discontinuities found in the solar wind.

The cost of the 'Daughter' satellite, development of which is scheduled to start early in 1974, is estimated at 23.4 million accounting units* at mid-1973 prices. The HELOS project development phase should start in mid-1975 and the satellite will cost an estimated 63 million accounting units at mid-1973 prices.

TSIOLKOVSKY MUSEUM

Local people call south-west Kaluga the 'space district' as it is there that Tsiolkovsky State Museum of the History of Cosmonautics spreads over the high bank of the River Yachenka, a tributary of the Oka. Nearby, in a small park, is the grave of the scientist, and not far away is the small house in which he worked. Near Tsiolkovsky's grave has now been mounted a replica of Vostok and its carrier rocket.

Konstantin Eduardovich Tsiolkovsky wrote that the basic purpose of his life was to do something useful for mankind, and somehow to help the progress of humanity. This became the inspiration for many of those who continued his cause, says *Novosti*, including designers and scientists who built the spacecraft and launch vehicles and Yuri Gagarin and his fellow-cosmonauts.

Although the museum is still young it already has over 1,000 exhibits and more are being added all the time. One of the most nostalgic items is Gagarin's flight log in which he jotted down notes during the world's first space flight. There is the actual capsule in which Valeri Bykovsky made his orbital flight and there are replicas of various unmanned space vehicles, from the first sputnik to the 12.2 ton space laboratory *Proton 1*. In the past 5 years nearly 2,000,000 people have visited the exhibition.

Of great interest are 20 hitherto unknown letters from Tsiolkovsky to Professor A. L. Chizhevsky dating back to the 'twenties in which the scientist expresses his pleasure that his works were beginning to receive wide circulation.

In the courtyard of Tsiolkovsky's house, one can see the small bitch Luna which has 'taken part in some important experiments in space medicine'. She has now been joined by the dog Ugolyok, which flew in *Cosmos 144*.

The museum is more than a repository of exhibits, the *Novosti* report continues; it is also a research centre of space science and the venue for national research conferences on aeronautics and space medicine. Its research associates not only hold lectures but also take part in preparing work on the history of astronautics and its development.

* *One Accounting Unit = $ US 1.2*

SATELLITE DIGEST — 61

A monthly listing of all known artificial satellites and spacecraft, compiled by Geoffrey Falworth. Information is based on that supplied by the Space Department of the Royal Aircraft Establishment, Farnborough, NASA, Satellite News and BIS sources. For information on the derivation of orbital parameters, abbreviations, etc., see July 1972 issue p. 262.

Continued from July issue, p. 272

Name, designation and catalogue number	Launch date, lifetime and descent date	Shape and weight (kg)	Size (m)	Perigee height (km)	Apogee height (km)	Orbital inclination (deg.)	Nodal period (min)	Launch centre, launch vehicle and payload/launch origin
Cosmos 547 1973-06A 6353	1973 Feb 1.36 11.8 days (R) 1973 Feb 13.2	Sphere-cylinder 4000?	5 long? 2.44 dia	203	310	64.97	89.63	Plesetsk USSR/USSR (1)
Molniya 1Y 1973-07A 6356	1973 Feb 3.25 5 years?	Cylinder-cone + 6 panels + 2 antennae 1000?	3.4 long 1.6 dia	470 578	39164 39772	65.00 65.00	703.15 717.6	Plesetsk USSR/USSR (2)
Cosmos 548 1973-08A 6359	1973 Feb 8.56 12.7 days (R) 1973 Feb 21.3	Sphere-cylinder 4000?	5 long? 2.44 dia	205 171	300 317	65.38 65.39	89.55 89.37	Plesetsk USSR/USSR (3)
 1973-08D 6367	1973 Feb 8.56 16.43 days 1973 Feb 24.99	Sphere?	2 dia?	159	453	65.42	90.61	Plesetsk USSR/USSR (4)
Prognoz 3 1973-09A 6364	1973 Feb 15.05 10 years	Domed cylinder + 4 panels + 2 booms 845	1.5 long? 1.75 dia?	590	200000	65.0	5783	Tyuratam-Baikonur USSR/USSR (5)
Cosmos 549 1973-10A 6373	1973 Feb 28.19 8 years	Cylinder + vanes?	2 long? 1 dia?	513	545	74.02	95.23	Plesetsk USSR/USSR

Supplementary Notes:

(1) Transmitted at 19.995 MHz.
(2) 27th communications satellite in Orbita network. Orbital data at 1973 Feb 8.7 and Mar 1.0.
(3) Orbital data at 1973 Feb 9.2 and Feb 14.1.
(4) Ejected from 1973-08A at 1973 Feb 20.
(5) Third Soviet solar observatory spacecraft to study solar processes and solar disturbance forecasting techniques from a highly-elliptical Earth orbit studies solar activity and its long-term influence on Earth's upper magnetosphere and the interplanetary medium for correlation with ground-based solar observations. Onboard instrumentation includes a solar-oriented X-ray spectrometer measuring solar radiation between 1500 and 30000 eV, a solar-oriented scintillation spectrometer measuring gamma radiation between 30000 and 350000 eV, a spectrometer and semiconductor measuring solar proton flux between 1.0×10^6 and 35×10^6 ev and α particles and heavy nuclei in several energy ranges, a Cerenkov counter measuring electron flux between 40000 and 140000 eV, a scintillation spectrometer measuring proton flux between 30000 and 210000 eV, an ion spectrometer measuring energies of positive helium ions between 0.1 and 16. keV, a boom-mounted loopantenna measuring solar radio emissions between 100 and 700 kHz. Similar to Prognoz 2 (1972-46A) the spacecraft studies solar corpuscular, gamma and X-radiation, solar plasma flux and its interaction with Earth's magnetosphere and studies Earth's magnetic fields. Prognoz 3, constantly solar oriented following nominal solar acquisition manoeuvres during first apogee, consists of a hermetically-sealed, inert gas-filled, cylindrical main structure containing scientific instrumentation, data handling systems and telemetry operating at 928.4 MHz, solar sensors and orientation subsystems, thermal controls and power conversion systems while the spacecraft's exterior holds four solar cell panels deployed after orbital insertion, solar sensors and solar orientation optics, nitrogen gas jet thrusters for attitude control and nitrogen gas supply containers. Initial telemetry indicated that all onboard systems were operating nominally, Prognoz 3's apogee over Earth's sunward hemisphere providing maximum opportunity for the spacecraft to study Earth's magnetosphere and interactions along the magnetospheric boundary and, in combination with Prognoz 1 (1972-29A) and Prognoz 2, acquires simultaneous solar wind measurements from differing altitudes. Prognoz 3 data is being correlated with data acquired by Lunokhod 2 (1973-01D) in studies of local lunar magnetic field variations.

Decays:

Cosmos 524 (1972-80A) decayed 1973 Mar 25.20, lifetime 164.64 days.
Cosmos 526 (1972-84A) decayed 1973 Apr 8, lifetime 165 days.

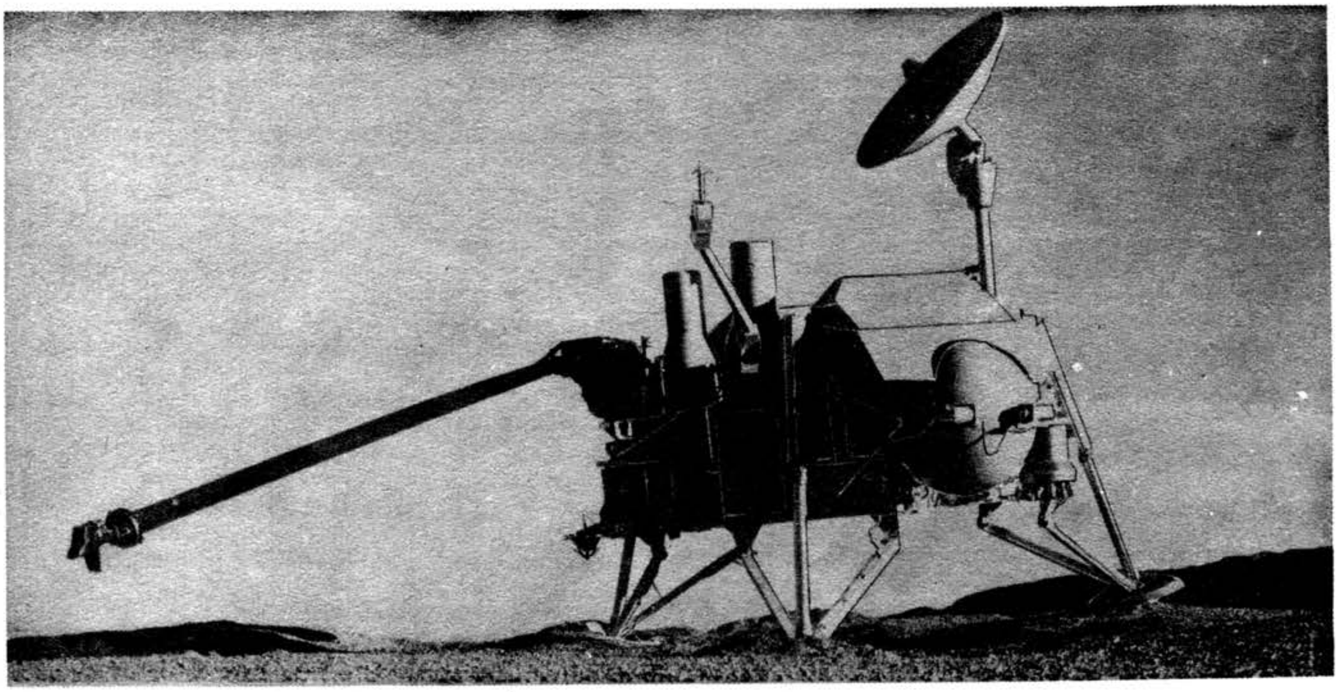
Amendments:

Operations 7329 (1970-69A) third orbit perigee is 31947, apogee is 39855, inclination is 10.3, period is 1441.9. Amend Supplementary Note (1) to read: Orbital data at 1970 Sep 1.0, Sep 15 and Oct 1.0
Molniya 1Q (1970-77A) lifetime is 5.5 years.
Oso 7 (1971-83A) lifetime is 2.5 years.
Heos 2 (1972-05A) lifetime is 2.5 years.
Molniya 1V (1972-25A) lifetime is 1.7 years.
Sret 1 (1972-25B) lifetime is 1.7 years.
Molniya 2B (1972-37A) lifetime is 2 years.
Molniya 2C (1972-75A) lifetime is 5.5 years.
Cosmos 523 (1972-78A) lifetime is 153.49 days, descent date is 1973 Mar 7.97.
Cosmos 524 (1972-80A) launch date is 1972 Oct 11.56.
Molniya 1W (1972-81A) lifetime is 5.1 years.
Cosmos 537 (1972-93A) launch centre is Tyuratam-Baikonur.
Intercosmos 8 (1972-94A) lifetime is 91.76 days, descent date is 1973 Mar 2.67.
Molniya 1X (1972-95A) lifetime is 2.1 years.
Molniya 2D (1972-98A) lifetime is 1.7 years.
1972-101A, lifetime is 10^6 years, weight is 350?, size is 1.7 long?, 1.4 dia?, perigee is 32100, apogee is 39660, inclination is 10.1, period is 1441.0, launch centre is ETR LC 13, launch vehicle is Atlas Agena D.

Readers may be interested to note that other contributions by Geoffrey Falworth are appearing in the 'Journal of the British Interplanetary Society' e.g. 'Objects in Selenocentric Orbit' (in two parts) in JBIS Vol. 26 No. 6 June 1973 and No. 7, July 1973, respectively.

NEW MAPS OF MARS*

By C. A. Cross, FRAS, FBIS.



NASA's next major exploration of Mars will involve two Viking spacecraft to be launched in 1975. Each craft will release a lander component with an automatic biological laboratory to seek evidence of life processes in the Martian environment. Prime target for the first lander is the valley area of *Chryse* 19.5 deg N, 34 deg W, at the north-western end of the 4,830 km (3,000 mile) long, 6,010 metres (20,000 ft.) deep, Martian 'Grand Canyon' (see pages 300 and 302). The rift system emerges into a series of long channels which resemble dried-out river beds. Second site is *Cydonia* in *Mare Acidalium*, 44.3 deg N, 10 deg W, at end of southernmost reaches of the north polar hood, a hazy veil which shrouds the polar regions during winter and may carry moisture.

Martin Marietta Aerospace

With this special illustrated feature we salute the team of scientists at NASA's Jet Propulsion Laboratory in Pasadena who achieved one of the greatest triumphs in the entire history of interplanetary exploration – the close inspection of the planet Mars. The author Charles A. Cross, a well known member of the British Interplanetary Society, has been closely associated with the interpretation of Mariner-Mars photographs and has won a deserved reputation for the high accuracy of his work. In a previous *Spaceflight* article [1] Mr. Cross described the preparation from Mariner 6 and 7 photographs of maps covering one seventh of the surface of Mars. The present article deals with the further work he has carried out in the preparation of maps of the whole of the planet from Mariner 9 pictures. Details are given of maps prepared by other workers, and finally the topography of Mars is described and the various interpretations discussed.

Kenneth W. Gatland

Introduction

Sixteen years ago, on 1 December 1956 (nearly a year before Sputnik was launched) I presented a paper to the British Interplanetary Society on 'The Use of Probe Rockets [2]. This was the first detailed analysis of the way in which instrument-carrying space vehicles might be used to explore the Solar System. In it I correctly predicted that the most useful observations might be made by taking a small telescope to within a few thousand kilometres of Mars and transmitting pictures back to Earth. I therefore have had a special interest in the Mariner missions, and count myself doubly fortunate in being able to play a part in the interpretation of the data they have secured.

The Mariner Missions

The technical details of the Mariner 9 mission have been outlined in *Spaceflight* [3], and fully detailed in the literature [4], but some simple comparisons of Mariners 4, 6 and 7, and 9 give an interesting picture of evolution towards a more efficient return of information.

It is evident that Mariner 4 was limited by the very low rate at which information could be returned, whilst for Mariners 6 and 7 the data return was limited by the amount of

TABLE 1. Comparison of Mariner Missions.

Mariner number	4	6 and 7	9
Number of pictures obtained	22	197	7,329
Elements per picture	4,000	665,280	665,280
Bits per element	6	9	9
Transmitter watts	10	20	20
Picture transmission time	1 hour	5½ min.	5½ min.

Element per picture (commercial TV) – 200,000.

* ***Based on a special presentation to the British Interplanetary Society at Caxton Hall, London, on 8 March 1973.***

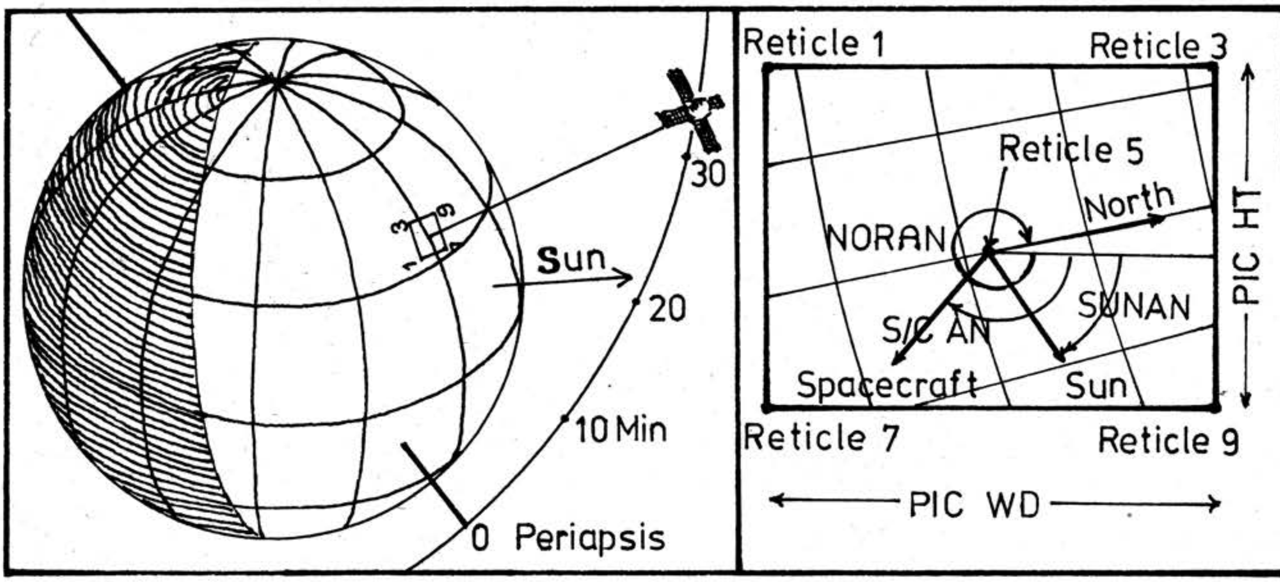


Fig. 1. EXPLANATION OF LIBSET SEDR DATA'

The following data are given for each picture:

Symbol	Meaning
DAS TIME	Spacecraft clock time of picture in 1.2 secunits.
CAM–REV	Camera (A or B) and orbit revolution No.
PIID	Picture identifier number.
SHUTTER TIME	Greenwich mean time of picture.
FILTER	Filter number, 1 to 8.
EXPOSURE	Exposure time in milliseconds.
TFP	Time from periapsis in hours, mins and secs.
LOCAL TIME	12 plus (SUNLON - LON 5)/15.
R MAG	Distance from spacecraft to planet centre in km.
S/C TA	Spacecraft true anomaly in degrees.
SUNLAT/LON	Latitude/longitude of subsolar point.
S/C LAT/LON	Latitude/longitude of subspacecraft point.
Q LAT/LON	Latitude/longitude of picture principal point.
PIC HT/WD	Picture height/width in km.
NORAN	North direction on the planet in degrees.
PIXEL SIZE	Projected pixel size in km at reticle 5.
SUNAN	Sun direction on planet in degrees.
S/C AN	Subspacecraft direction on planet in degrees.

Data given for reticle points 1, 2, 5, 7, and 9 are as under:

Symbol	Meaning
LAT(X)	Latitude of reticle point in degrees.
LON(X)	Longitude of reticle point in degrees.
VAR(X)	Spacecraft zenith angle in degrees.
SLAR(X)	Solar zenith angle in degrees.
PAR(X)	Angle subtended by Sun and spacecraft in degrees.
SRR(X)	Distance of reticle point from spacecraft in km.

information which could be collected during the half hour 'near encounter' period. This restriction was removed for Mariner 9 by its insertion into an orbit around Mars. There is a close analogy here between the Lunar and the Martian probes. The Lunar Rangers produced only a few hundred pictures, which were published in their entirety. Mariner 6 and 7 pictures have similarly all been published in a book [5] which may be recommended as an invaluable data source. *(It is available at $4.25 from the US Government Printing Office. Ed.).* Mariner 9, however, like the Lunar Orbiters, has produced so much data that there can be no question of its complete publication. How then is it made available to scientists and other interested parties?

The Mariner 9 pictures are available from the World Data Center by specifying picture identifier numbers. These numbers are listed in the microfilm LIBSET SEDR data file. Fig. 1, which is the explanatory panel from this file, shows the considerable amount of information needed to specify completely each picture. Perhaps the only point which is not self evident in Fig. 1 is that a reticle point such as the corner in space of a picture showing the limb of the planet is regarded as lying on the plane through the planet's centre at right angles to the spacecraft radius vector.

The LIBSET SEDR data allows one to choose pictures showing required areas of the planet. Individual pictures cost 70 cents each, with a handling charge of $2.50 irrespective of the number ordered. Thus a complete set of 7,329 pictures would cost $5,132.80. Perhaps not many BIS members will wish to go to this length, and for those who merely require a sample of the pictures for close inspection the commercially available 35 mm slides may be recommended.

Preparation of the Maps

To map the whole of a world its spherical surface must be spread out flat. This cannot be done without distortion, but we may decide within limits what kind of distortions are introduced by choosing amongst the map projections which cartographers have developed for mapping our own Earth. For the Mars maps I have chosen the conformal projections. These preserve shapes and directions undistorted (so that circular craters remain circular) but they sacrifice uniformity of scale. The surfaces between latitudes 60° North and 60° South are shown on Mercator projections, and the North and South polar regions are shown on Polar Stereographic projections. In the former the scale increases with latitude, and is doubled at latitude plus or minus 60°. In the latter the scale increases with distance from the pole, and is doubled at the equator. Care must be taken in measuring distances on the maps to use the scale appropriate to the latitude.

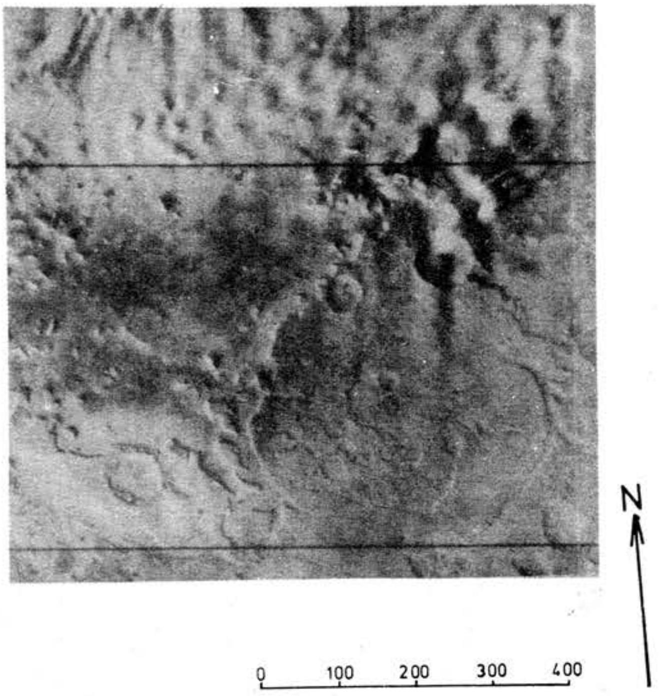


Fig. 2. Ancient Volcanic Shield in the Nilokeras Region. Picture centred at 43°North, 325°West. High level clouds of the North Polar hood obscure top third of this picture.

The prime data source for the maps is of course the Mariner 9 pictures. Mapping sequences, delayed by the great dust storm, commenced on 2 January 1972, and were completed to latitude 40 to 50° North by 2 April. At this time it was still impossible to see surface details at higher northern latitudes because of the extensive high level cloud cover (Fig.2) known to astronomers as the 'Polar Hood', which is found in early spring over both poles.

Because of the steady movement of Mars around the Sun, whilst the Mariner orbit plane remained fixed in space, the vehicle commenced to pass through the shadow of the planet during each orbit on 2 April. This deprived the vehicle of power from the solar cells for periods of up to 1½ hours per 12 hour orbit, and TV pictures were not transmitted so as to conserve power. When the continuing movement of Mars around the Sun had terminated the series of solar occultations on 4 June and picture transmissions could be restarted, it was found that this haze had cleared, and the mapping sequences were completed. Because of the increasing Earth - Mars distance, and possibly because of remnants of the haze, there is some deterioration of quality in these final pictures.

Over 1,500 of the pictures were assembled into uncontrolled photomosaics by the US Geological Survey staff at Flagstaff, using the reticle positions calculated from the spacecraft tracking data (as given in LIBSET SEDR). These USGS photomosaics (Fig. 3) attain a positional accuracy within 60 km, but Merton Davies [6] has calculated mean square corrections for some 1,000 control points on these photomosaics, and the positional accuracy of my maps has been improved by applying these corrections.

The preparation of the maps with charcoal and stump drawing has followed the techniques already outlined [1], using the photomosaics and where ever possible individual Mariner 9 pictures. For the North polar regions no photomosaics were available, and here the maps have been constructed directly from Mariner 9 pictures and Merton Davies' net of control points.

Positions are defined in Aerographic coordinates, in which latitudes are calculated, as on Earth, from the local verticals, instead of from the line joining the point to the centre of the globe (which gives its aerocentric coordinates). Because of planetary rotation Areographic latitudes are some 1/3° larger than areocentric in the middle latitudes.

Over most of the globe the size of the smallest crater shown is set by the map scale as 20 km diameter at the equator, and 10 km at latitude 60°. Comparison of the map with the pictures shows that this has meant leaving out a good deal of fine detail. Because of automatic gain control, however, the Mariner pictures only show the boundaries of changes in surface albedo. An attempt has been made to show the light and dark area more correctly by using information from James Roth's Earth based maps [7] to supplement the local albedo variations shown by Mariner.

There is not space in this article to reproduce all six maps at a reasonable scale, so I have chosen the South West Quadrant (Fig.4) and the South Polar Map (Fig. 5) as giving a representative sample of the Martian topography. The light and dark areas have been labelled with the classical names approved by IAU Commission 16. All maps will be published in September by Mitchell Beazley Ltd., as an *Atlas of Mars*, with explanatory text by Patrick Moore, and with Mariner pictures and mosaics of special areas keyed to the maps.

Other Maps of Mars

The first map based on Mariner 9 pictures to be published was the one prepared by the USGS from the mosaics. The version which appeared in *Sky and Telescope* in August 1972 [8] comprised an equatorial mercator, and a map of the South pole. Later versions included the North pole. The maps were drawn to a scale of 1:25,000,000, but this scale was considerably reduced in reproduction. They showed topography only, omitting the light and dark areas.

Another map has been published by the National Geographic Society, in their *Magazine* for February 1973. It is made up from three Lambert equal area hemispherical projections, centred on longtitudes 0°, 120°, and 240°, together with two small polar projections. The maps, which are in colour, were prepared by Jay. L. Inge, who was one of the artists for the USGS maps. At a mean scale of 1:31,770,000 they are not able to display quite as much detail as the USGS maps, but the light and dark markings have been included. The magazine contains an interesting article and supporting pictures on a popularised level. A rather more scientific article, without maps, has been published by Professor Bruce Murray [10].

A 16 in. globe of Mars is in preparation in the United States, and should be available when this article is published.

Topography of the South West Quadrant

This quadrant of Mars is dominated by the great equatorial valley, which starts in *Tractus Albus* and *Noctis Lacus*, and runs Eastwards for 3,500 km through *Tithonius Lacus, Melas Lacus* and *Coprates*, before turning Northwards in *Aurorae Sinus* to run through *Chryse*. The upper (Western) end of this

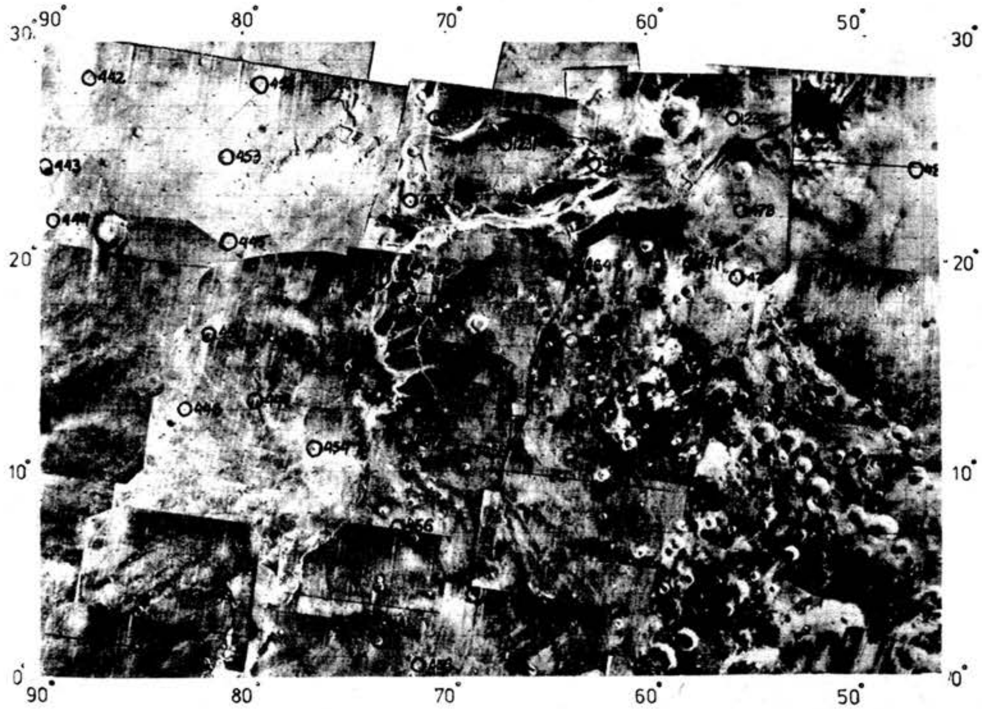


Fig. 3 U.S. Geological Survey Photomosaic MC10. Mercator Projection, original scale 1:5,000,000.

valley starts as a maze of intersecting canyons, each as large as Earth's Grand Canyon, in the shadow of the lofty volcanic cones of *Nodus Gordii, Pavonis Lacus*, and *Ascraeus Lacus.* These form the Southern half of the *Tharsis* volcanic province, with *Nix Olympica* and several smaller cones in the Northern half (off this map). The whole volcanic province forms a vast plateau, elevated some 15 km above the mean surface of the planet. In it the normal random cratering is virtually absent. The simplest explanation is that the meteoric impact craters have here been buried under the ash and lava of this youngest volcanic region. Outside this map there are other volcanic regions, such as that in *Elysium* which shows some meteorite craters, and another in *Nilokeras* (Fig. 2) which is so ancient that it has been heavily damaged by impact craters. Clearly vulcanism has not been restricted to the most recent Aerological eras. The observation of these true volcanic features on Mars should help to resolve the long controversy between volcanic and meteoric mechanisms on the Moon.

Although the great equatorial valley runs downhill eastwards for the whole of its length, it should not be regarded as primarily an erosion feature. There are totally enclosed subsidence areas in *Tithonius Lacus* and in *Ophir,* with chains of subsidence craters running between them. The whole complex is perhaps best interpreted as a rift valley, opened up by crustal tension. Such features on Earth are usually attributed to the movement of tectonic plates, and there are similarities in scale and structure between the great Martian Rift Valley and the Red Sea.

If the system was born as a rift valley, there are clear signs of its subsequent modification by erosion. In the upper section of *Tithonius Lacus* (Fig. 4), where the valley is about 100 km wide and 6 km deep, the Southern wall is cut into by branching tributaries best explained as erosion gulleys formed by the inflow of surface water. In the middle section through *Melas Lacus* and *Coprates* the walls are not eroded, but the valley floor looks as though it has carried water. In the final sections through *Aurarae Sinus* and *Chryse* (Fig. 6) the valley widens out, and becomes shallower, with a floor showing a complicated array of sinuous channels and debris-littered sediment fans. Here the North trending erosion channels cut across the East - West rift valleys.

There are sinuous 'arroyo' channels in various locations on the planet, of which the example in *Mare Erythraeum* is perhaps best known (see 40°W, 30°S on Fig. 4). To my mind however the most convincing evidence of water flow is to be seen in the channels leading Northwards and Eastwards around the dark elevated area of *Lunae Palus* (Fig. 3). All this very positive evidence of liquid erosion on Mars shows that in the past the atmospheric pressure must have been much higher than its present value below the triple point of water. (as pressure is reduced the boiling point of water falls from the value of 100°C at 1,000 millibars which we know on Earth, until at 6.1 millibars it has reached 0°C. Below this pressure liquid water cannot exist, and ice when warmed sublimes directly into vapour just as solid carbon dioxide 'dry ice' does at one atmosphere pressure).

[*Continued on page 304*

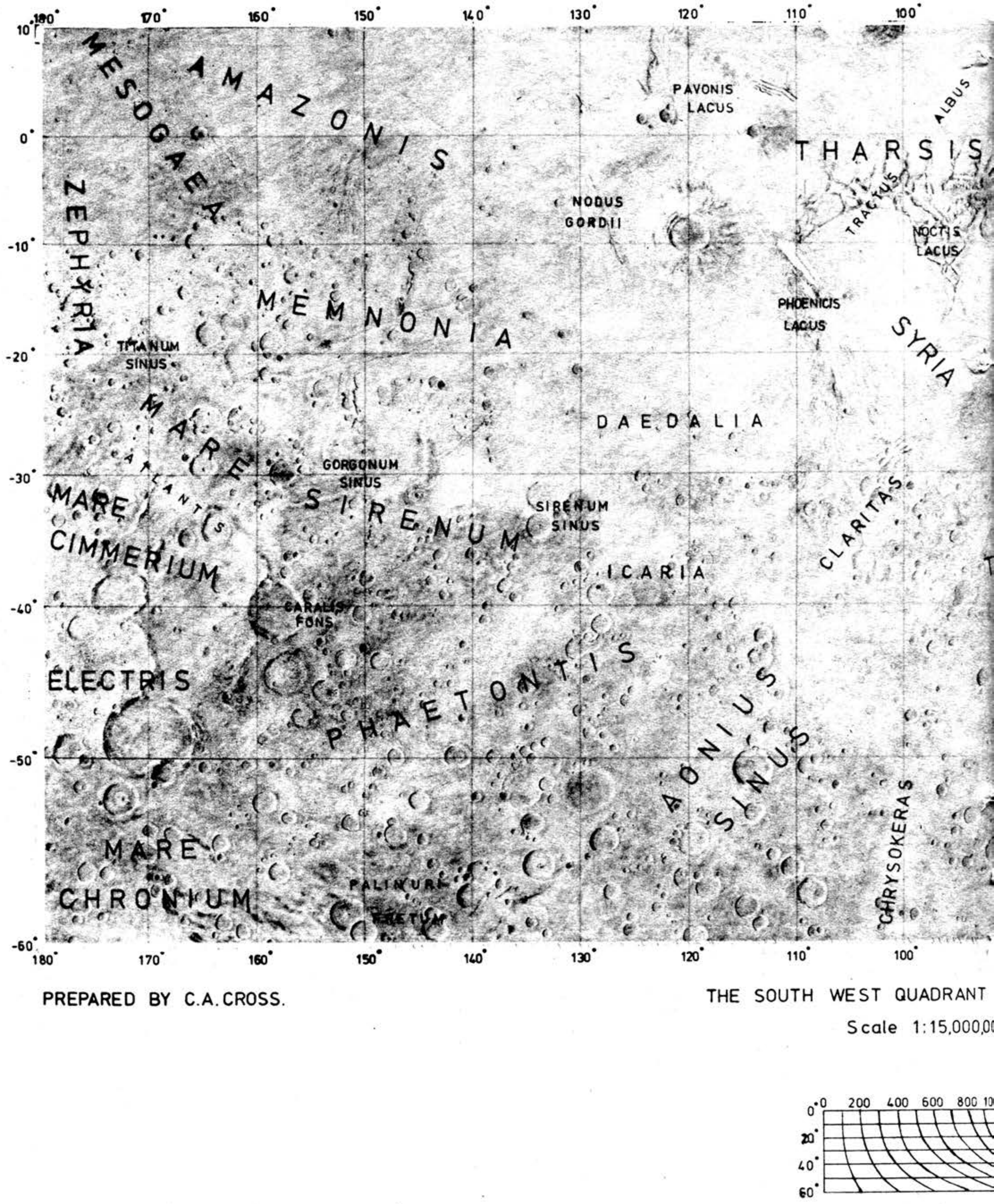
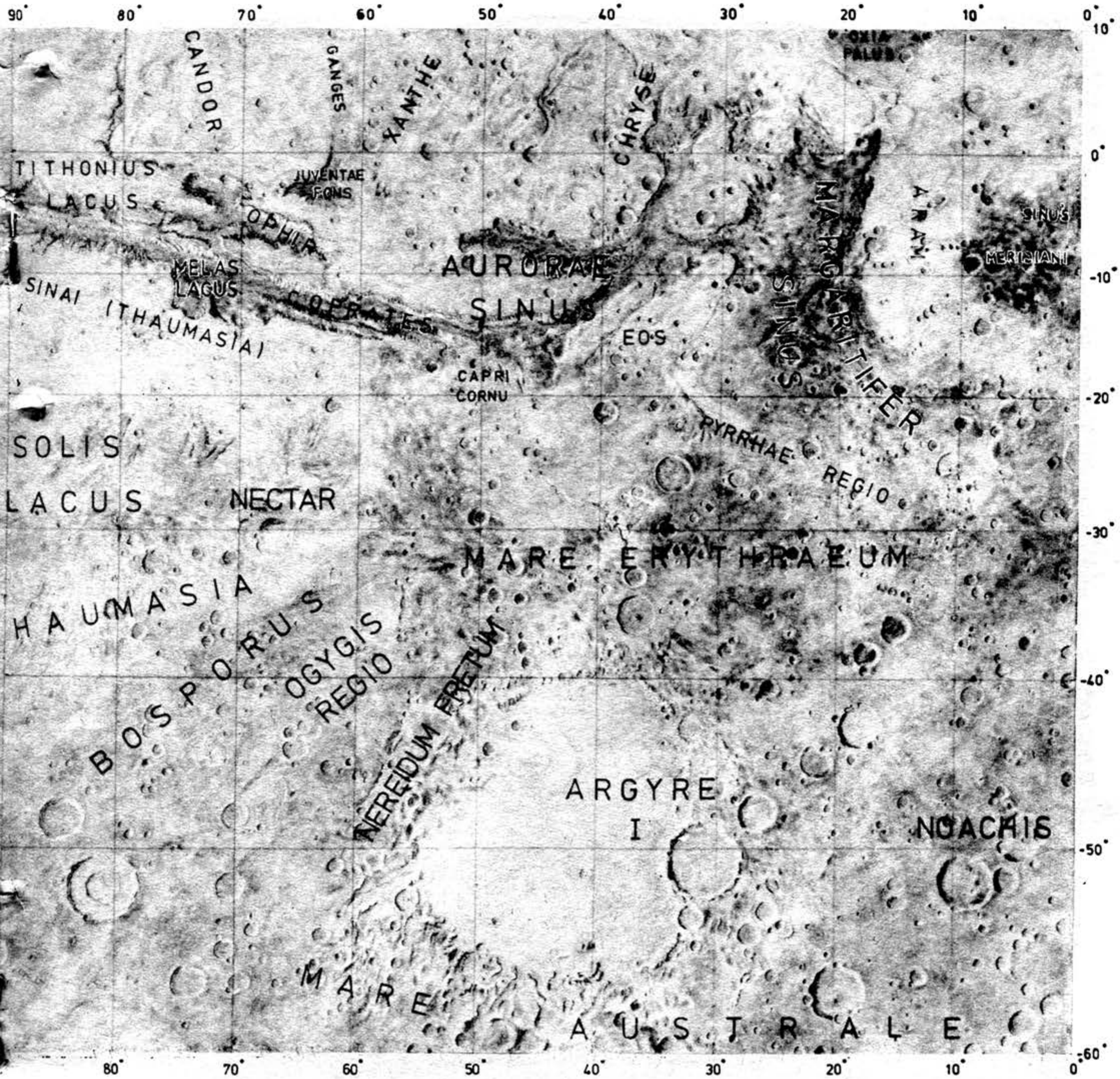
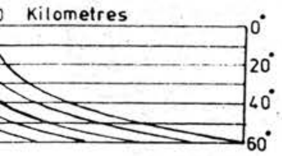


Fig. 4. The South West Quadrant of Mars. Mercator Projection.



F MARS. MERCATOR PROJECTION. SEPTEMBER 1972.

) at the equator



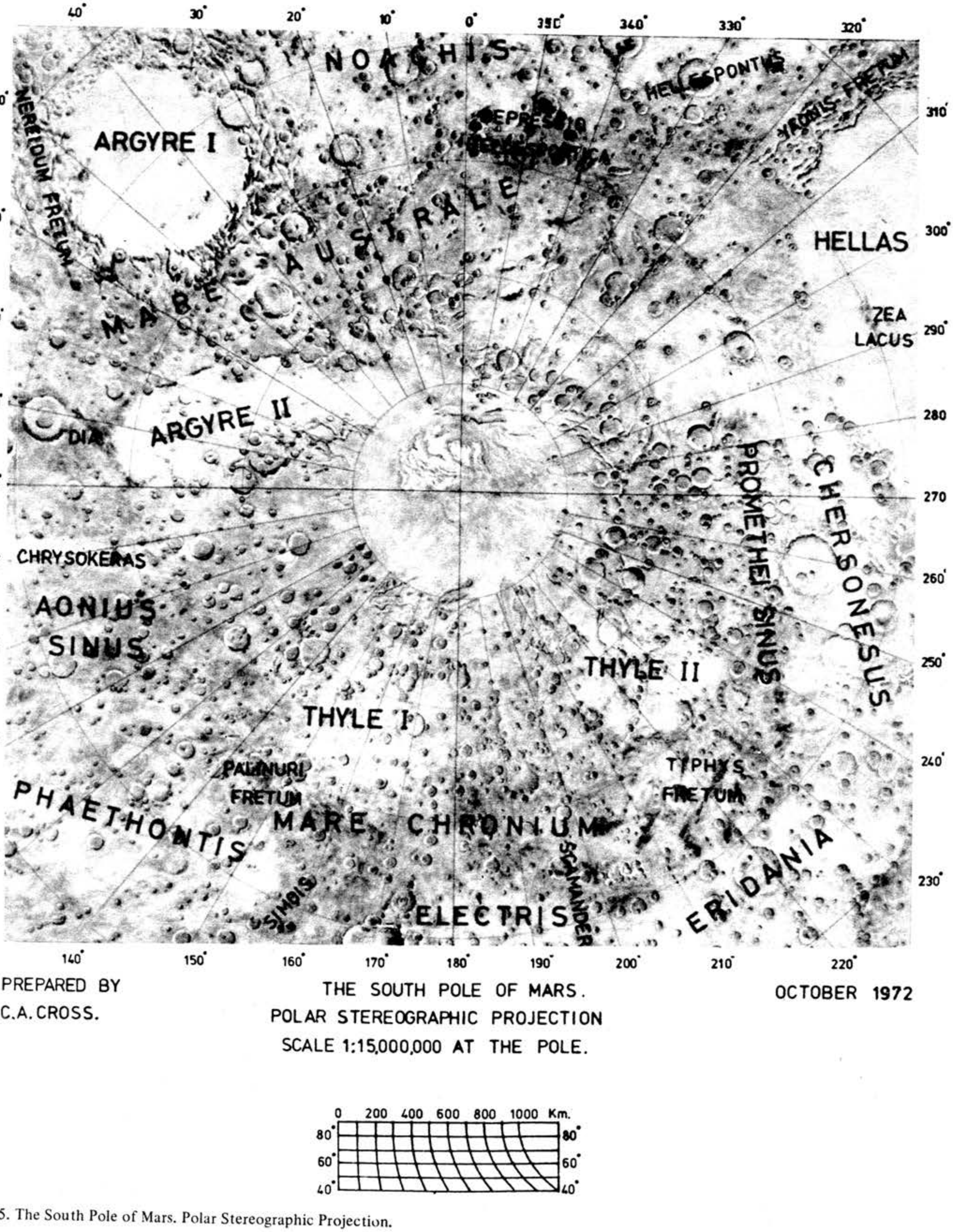


Fig. 5. The South Pole of Mars. Polar Stereographic Projection.

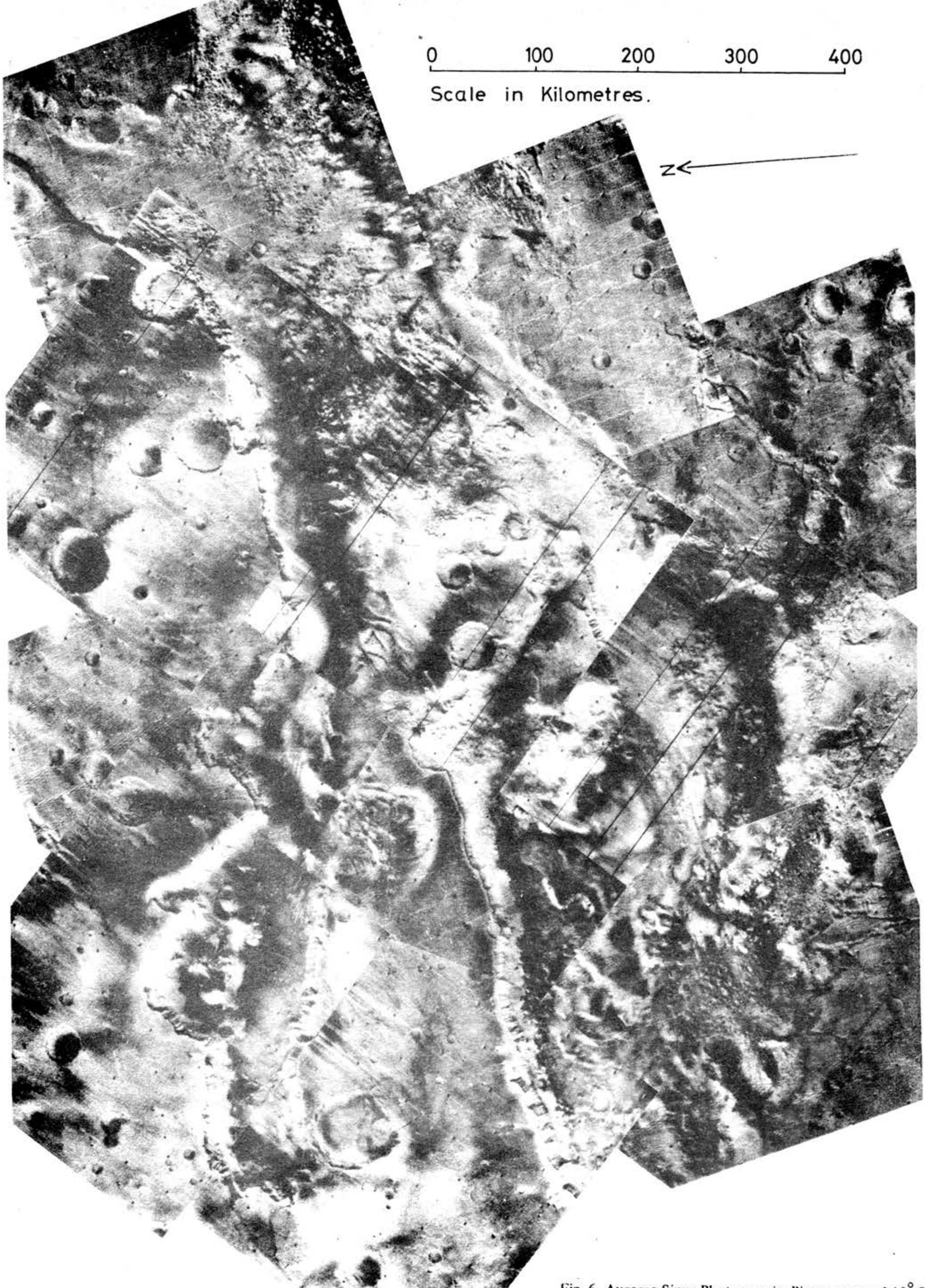


Fig. 6. Aurorae Sinus Photomosaic. Picture centred 10° South West. The rift valley main channel runs from the bottom.

The South Polar Topography

The South Polar map has been drawn with considerable overlap of the S.W. Quadrant, and the prominent feature of *Argyre 1* may be seen on both maps. This feature is well known to telescopic observers as a large light patch. It turns out to be an enormous 1,500 km diameter crater (Fig. 7) with a featureless flat floor. It is very like a circular lunar mare in everything except colour. It shows an interesting ghost ring in its north-eastern part.

The map shows the remnant of the polar cap in the form in which it survived the southern summer. The temperatures measured upon it were too high for solid CO_2, so there must be some water ice there.

Like the *Tharsis* volcanic region, the immediate neighbourhood of the pole (within 10°) is virtually devoid of craters. This also appears to be due to their burial by a surface deposit, which in this case appears to be made up of numerous regular layers only 50 to 100 metres thick. They give the ground a typical laminated appearance. In the transition region between laminated and normal terrain the smooth laminations only cover irregular patches (Fig. 8) and rougher cratered ground is exposed in the areas between. The formation of these deposits at both poles is not fully understood, but is presumably connected in some way with the condensation and sublimation of the polar caps.

Future Exploration of Mars

Since all our information so far has been obtained remotely from orbit, the next step forward requires a landing. Unfortunately Russia's Mars 3 failed before it could send any significant data, but we may expect that they will try again, particularly since the Americans have planned to land their Viking in 1976 [11].

The Viking lander is rather like a Lunar Surveyor provided with a nuclear power plant instead of solar cells. It will measure the Martian weather (temperature, pressure, and wind speed and direction), take stereo colour pictures by a dual facsimile camera system, and test soil samples for living organisms. The landing must be chosen to give these biological experiments the best chance of success, so attention will be concentrated on the lowland areas. The great basin of *Hellas,* although probably the lowest area on the planet, is at high Southern latitudes, which means low temperatures and would also make landing difficult. A low lying equatorial region is indicated.

The Viking lander will not be committed until detailed and extensive surveys have been completed by the Viking orbiter, but I would suggest that the flat floor of the blind canyon in *Aurorae Sinus* is a strong candidate for investigation (Fig. 4). This area is shown in more detail in the bottom left of the mosaic of Fig. 6. Its dark floor could well have been the site of a protected shallow lake of much greater permanence than the periodic floods which formed the neighbouring erosion channels.

It is difficult to gauge the chances of success of the Viking mission. Its four biological experiments can only be calibrated to detect life chemistries like our own, but Martian life may have evolved on very different lines. If all four show negative results it may be safe to assume that there is no life on Mars capable of adversely affecting our own planet. Strangely enough, positive tests will raise both the strongest motives for more detailed exploration, and the greatest difficulties in carrying it out without risk to the respective biospheres. I doubt that any facility such as the Lunar Receiving Laboratory could guarantee perfect isolation. Perhaps the successors to

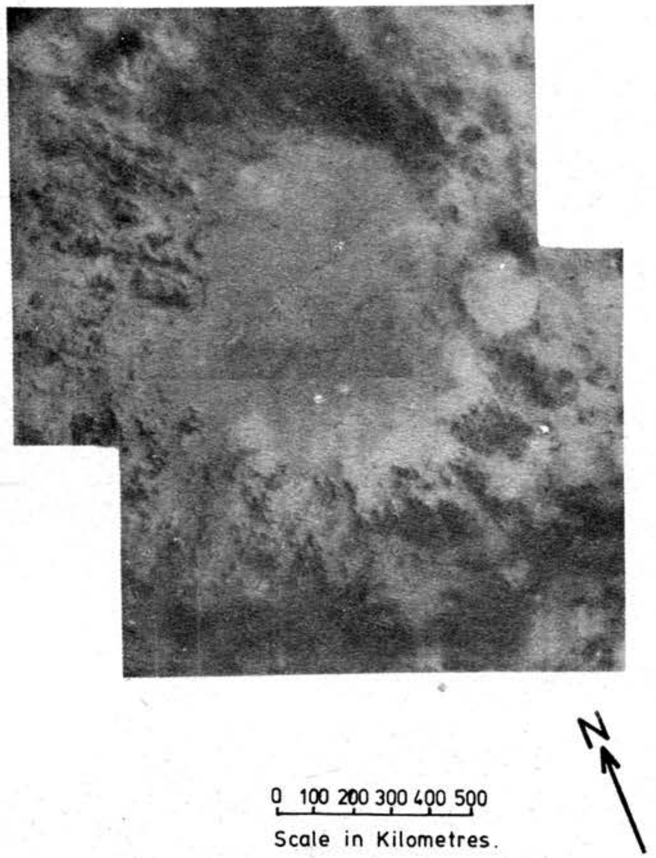


Fig. 7. Argyre 1. Picture centred 50°South, 45°West. A mosaic of two A camera pictures taken at a range of 5,400 km 57 min. and 58 min. 25 sec. after periapsis on 10.1.72.

Skylab could provide adequate quarantine for the examination of biologically active samples from Mars.

Only when all these problems have been solved may men venture to explore Mars directly. They will probably travel there in vehicles assembled by space shuttles in Earth orbit.

Interpretation of the Topography

It must be realised that only the most tentative and speculative interpretations have yet been made. It will take many years to develop sensible and consistent models capable of explaining the present observations and the further ones which will be acquired by future instrumented and eventually manned missions.

Mars is a much more interesting and complicated world than the Moon. It shows clear evidence of differentiation in the volcanic provinces of the Northern hemisphere, yet preserves large areas of impact crater scarred surface. If these do in fact represent the primaeval craters of the final stages of the planet's formation by cold accretion, then it is difficult to understand how they have survived with little more erosion than the Lunar Highlands.

Professor Murray [10] seeks to explain this by supposing that Mars has only just begun to warm up internally, to show vulcanism, and to begin the formation of an atmosphere. Dr. Sagan sees an answer in terms analogous to the ice ages of Earth, in which orbital and precessional changes occasionally combine to provide brief globally warmer intervals, when atmospheric pressure is raised, and liquid water becomes a

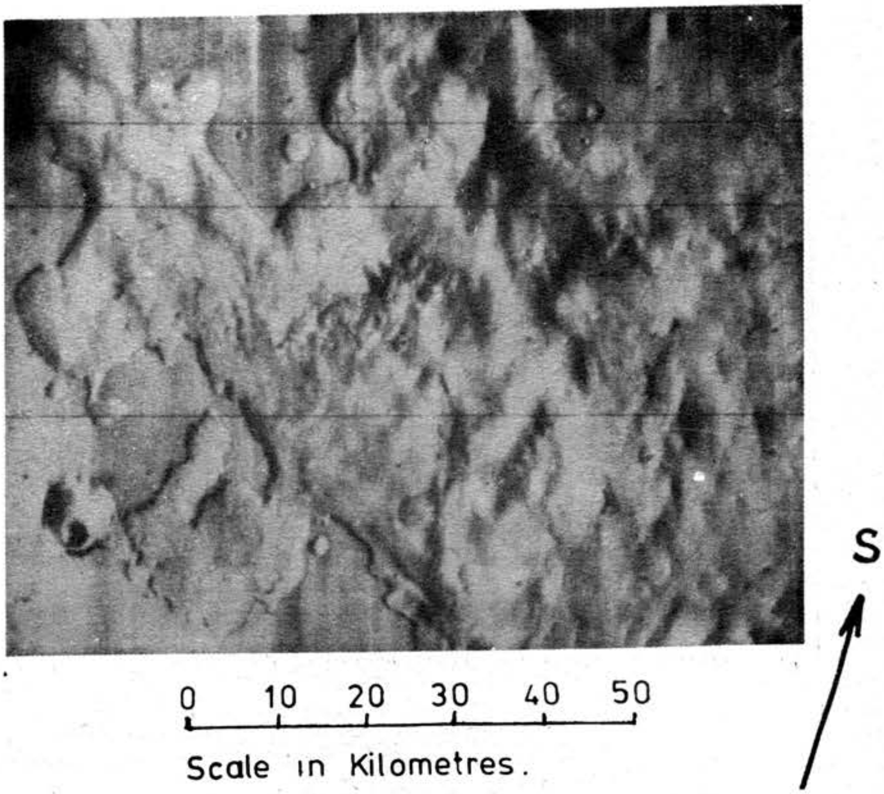


Fig. 8. South Polar Laminated Terrain, Transition region, Picture centred at 67° South, 326° West. One B camera picture taken from 3,627 km on 6. 2. 72.

possible constituent.

My own view is that Mars has already passed through its high temperature evolution. Because it is intermediate in size between the Earth and the Moon, the orogenic effects were also intermediate in scope and duration. Thus the high internal temperatures lasted longer, and produced much more positive surface evidence of vulcanism and crustal movement than was the case for the Moon, but the much smaller planet was not capable of sustaining the continuing high internal temperatures and activity characteristic of the Earth. During the peak of the volcanic activity on Mars we may suppose that the atmospheric pressure was high enough for the steam emitted to condense as liquid, and to cause erosion localised around the volcanic provinces. This would be only a transient phase, terminated by loss of CO_2 to space, and by permanent freezing of water into the polar regions.

Mars will remain a continuing challenge to scientists for many years. It is to be hoped that society will find it worth continuing to support their efforts to understand more fully the Solar System in which we all have our existence.

REFERENCES

1. C. A. Cross, 'Mapping the Surface of Mars', *Spaceflight*, **14**, 402, (1972).
2. C. A. Cross, 'The Use of Probe Rockets', *JBIS*, **16**, 148, (1957).
3. 'Mars Unveiled', *Spaceflight*, **15**, 151, (1973).
4. R. H. Steinbacher, N. R. Hayes, 'Mariner 9 Mission Profile and Project History', *Icarus*, **18**, 64, (1973).
5. S. A. Collins, 'The Mariner 6 and 7 Pictures of Mars', NASA SP-263.
6. M. E. Davies, 'Mariner 9 Control Net of Mars', Rand Report R-1122-JPL.
7. G. de Vaucouleurs, 'A Mars Chart for the Mariner Flights', *Sky and Telescope*, **41**, 283, (1971).
8. Mariner 9 Television Team, 'The New Mariner 9 Map of Mars', *Sky and Telescope*, **44**, 77, (1972).
9. K. F. Weaver, 'Journey to Mars', *National Geographic Magazine*, **143**, 230, (1973).
10. B. Murray, 'Mars from Mariner 9', *Scientific American*, **228**, 49, (1973).
11. D. Dooling, 'Project Viking', *Spaceflight*, **14**, 162, (1972).

KOROLYOV MUSEUM

The home of the late Academician Sergei P. Korolyov, the Soviet rocket designer, in Ostankino, Moscow, is being turned into a memorial house. It is located a few hundred yards from the titanium space obelisk on Peace Avenue in the base of which a 'cosmonautics museum' is now being installed.

The house is a two-storey stone building with a large balcony over-looking gardens. Korolyov was fond of the garden and spent many an hour resting there. The designer lived in the house for several years during the time he was in charge of a large team of scientists and engineers who created the early sputniks, the *Vostok* and *Voskhod* manned spacecraft and interplanetary probes. He often entertained his colleagues in the house and according to *Novosti*, it was the scene of some of the most profound and rewarding discussions. In the hallway is a small Postnikov sculpture 'To the Stars' presented to Korolyov by cosmonauts who signed their names on the pedestal.

FINANCIAL SETBACKS IN THE U.S. SPACE PROGRAMME

By David Baker

Introduction

Looking back at the first two decades of Western space activities the casual observer is shocked into sheer incredulity. The trained eye will indeed label 1973 as the winter of our discontent.

From a budget operating base of little more than $200 million in 1959 the National Advisory Committee for Aeronautics spawned into the National Aeronautics and Space Administration and by 1965 was receiving $5,200 million, providing employment for nearly 410,000 government and industry personnel. The situation is very different today.

In the light of recent events it is appropriate to review the situation over the past eight years and reach tentative conclusions about the future course of space activities in the United States.

The inflation began in fiscal year (FY) 1962 with the onset of the Apollo Programme and a general upsurge in supporting projects. In just three years the New Obligational Authority (NOA) rose five-fold to stand at a value approaching $5,400 million; this is a far cry from the $972 million four years earlier. The civil service workforce was still climbing and would reach 33,924 by the middle of 1966. But already the writing was on the wall.

In a vain attempt to begin work on Apollo follow-on ventures such as manned Earth-orbiting laboratories and circumlunar research modules NASA presented Congress with a massive request for appropriations. The contractor force had peaked at 376,700 in mid-1965 and NASA realised that once its cadre of specialist corporations began to lose themselves in other work the continued exploitation of trained personnel would prove too costly to support a separate space programme. Congress held firm, the Far East crisis turned thoughts to weapons production and the country tightened its belt for an expensive war. The NASA star was already beginning to wane.

Early in 1967, when NASA was preparing to send its leaders to face the Senate and House Committee scrutiny of the FY 68 budget, a catastrophic accident at Cape Kennedy took the lives of three astronauts and set the country against the agency if not the whole concept of Man-in-Space. Disillusioned by a lengthening war in Vietnam, hardened by student riots at home and frightened by the burning of cities by a black minority, the United States lost all sight of its wider objectives and raised the drawbridge on all non-military ventures.

Within six months of the disaster Congress had appropriated $4,589 million for FY 68, some $511 million less than requested and a loss of nearly 12% on the planned budget. Already more than 103,000 aerospace employees had lost their jobs in the previous two years, but this was just the beginning. Two years later, just months before the first manned landing on the Moon, the NASA budget was down $3,750 million. In the previous year workers had been laid off at the staggering rate of 1,000 per week and by mid-1970 nearly a quarter-million men and women had lost their aerospace jobs.

The effect on ancillary industries and community life was enormous. In the 2½ years beginning January 1968, the Los Angeles area lost 85,000 aerospace workers, taking with them an additional 50,000 persons working in supermarkets, stores, and service industries. At the end of this 2½ year period 93,000 persons were still claiming unemployment insurance. a 75% increase on the first half of the period and a reflection of the decreasing feed-through into other jobs.

By September 1970 North American Rockwell had dismissed 21,000 of its work force, Grumman had lost 4,000 (50% of the total), and the civil service had re-directed 2,700 employees. By far the worst hit area was to the Seattle area of Washington State. In one week Boeing had to lay off nearly 64,000 workers to prevent entire collapse and nearly three years later 15,000 men and women still queued at free food kitchens moved in by industrious samaritans from local stores and shops.

The picture was identical at NASA facilities. From a peak employment of 26,000 in late 1968 to 13,000 just four years later, the Kennedy Space Center echoed depressive cries of redundancy. Launch pads rotted, launch towers rusted and were pulled down, NASA executives polled local scrap merchants for the highest bid, and grass returned to the miles of concrete that once gave promise of a road to the stars. By mid-1970 the First National Bank at KSC had closed 4,000 cheque accounts, 2,500 deposit accounts, suffered a 75% loss on loans , and completed its last commercial transactions with industrial contractors.

By FY 72 a certain stability had been achieved. The budget was down to $3,100 million but in the 12 months from mid-1971 only 4,641 aerospace and civil service jobs had been lost. By mid-1973 total redundancies had topped the 300,000 mark and only 109,000 remained at work on the space programme.

What does the future hold? Where do we go from here? These are important questions raised at a critical time in the overall balance of programme planning, control and coordination.

NASA has always had to operate within the environment of changing political climates, inclement public support, and severe budget constraints. Criticised for not presenting a clear picture of Post-Apollo programmes in 1966 the agency developed a plan for utilising Apollo hardware in an extension of Earth orbital flights and presented this to Senate and House space committees early in 1967. Unimpressed, and unconvinced of the necessity to accelerate Post-Apollo plans, NASA received only minimal appropriations from Congress. This was the fateful turning point in the whole sad story of a retraction of interest in drawing from space the many goals and ambitions that could enhance the quality of life on Earth.

NASA, as an agency, has been sent to the whipping post for not promoting the application of space technique to Earth-based problems, criticised for not communicating with the man-in the-street and blamed for setting its sights too high in programme planning. The last great 'error' of judgement was instigated by the then outgoing administrator of manned space flight, Dr. George E. Mueller. Quite simply he expected the nation to willingly invest in the past decade of achievement, move ahead with new goals, and launch the United States on a spacefaring road of achievement and technological expertise.

It seems incredible today that just four years ago NASA was structuring its future role around lunar bases, Earth-orbit space stations housing 100 scientists, nuclear propelled voyages to Mars orbit and the establishment of the first colonies on the Red Planet. It is only in the last two years that the agency has openly accepted the cancellation of all these plans and substituted the simplified Earth-orbital programme now funded.

On the other hand the regrettable loss of government interest in space exploration, coupled with a reluctant acceptance of applications, has kept NASA hopping from one five-year plan to the next. Every year a new programme structure is proposed, only to be re-configured months later. In the past two years alone the space agency has had to cancel two Orbiting Solar Observatories, two High Energy Astronomical Observatories, four Grand Tour flights to the outer planets, an Appli-

cations Technology Satellite, and the nuclear rocket. All of these were programmes that had captured fiscal resources in earlier years and in the case of the nuclear rocket more than $1,400 million had been invested before outright cancellation. Ultimately the final responsibility must surely rest at the gates of political administration for not backing the agency with a long range objective tied to realistic funding levels. For NERVA the road had been long and arduous. From a planned 200,000 lb. thrust version in 1966 to a 75,000 lb. thrust re-work in late 1967, the first attempt to produce a flight rated nuclear stage took another blow just four years later with a proclaimed mandate for industry to pursue a 15,000 lb. thrust design. By the middle of 1972 it had been relegated to an already dust-covered shelf.

The appalling lack of foresight was underlined by a score and more of major projects that had come under the axe, invariably at a time when tests had vindicated the concept. Among the more significant was SNAP-8, SNAP-10, SNAP-50, Pluto, Rover, SNAP-2, the M-1, the 260-inch solid propellent motor, Voyager, Orion, and the capsule-landing proposal for Mariner-Mars 1971. The latter would at least achieve prominence as the first Mars orbiter. The list is incomplete,but testifies to the frustrated undertones of a decade and more of incredible achievement against odds more catastrophic than the space environment itself.

The Fiscal Year 1973 Budget

The FY 73 budget submission was detailed in the October 1972 issue of *Spaceflight* and we will only deal here with the Congressional amendments prior to the Conference Committee approval in July, 1972.

Research and Development appropriations for manned space flight were unchanged from the submitted values and Congress approved the $1,224 million request in its entirety. Likewise, space science was passed as submitted but an additional $12.5 million was voted in for applications. This added funds to the Small Applications Technology Satellite, the radio interference and propagation programme, Earth Observatory Satellite studies, and the global atmospheric research programme

Aeronautical research and technology was granted a $24 million increase (6.5%) by the Senate and approved by Congress for a total R&D authorisation of $2,637 million. With no changes in the Construction of Facilities and Research and Programme Management requests the overall NASA authorisation for FY 73 was passed at $3,444 million. Appropriations for the year were held at $3,408 million.

An increase of $29 million over the budget authority request of $3,379 million was made effective to honour pay rises and contractual adjustments.

In December 1972 the President ordered a period of constraint to keep overall Federal expenditure within the $250,000 million target set in late 1971. Accordingly, NASA was requested to reduce the budget authority and overall expenditure by 0.7%. Coming halfway through the fiscal year it brought additional demands on the administration of approved programmes.

Research and Development was reduced by $91 million, with Research and Programme Management cut by $15 million, re-configuring the budget authority from $3,408 million (see above) to $3,302 million. Outlays were cut by $179 million to limit expenditure to $3,062 million.

The most important project to suffer under the axe was the High Energy Astronomical Observatory, a programme first funded in FY 72 with launches at that time scheduled for 1975 and 1976 but already amended to 1975 and 1977 at the time of cancellation.

Application Technology Satellite G, originally scheduled for a launch in 1975 and put back to 1976 last year, was also cancelled, terminating all R&D effort on communications satellites. Work on nuclear propulsion and advanced nuclear power concepts was also halted with the immediate closure of the Plum Brook station in Ohio.

Work on the Shuttle has been hit again with a nine month postponement of the first orbital flight, now expected in early 1979. All work on the Quiet Propulsive Lift Jet and its related technology, including applications to short haul transport aircraft (strains of the H.S. 681?), was also deleted and reductions were made in the development, test, and mission operations portion of the manned space flight budget.

To summarise, NASA was required to reduce overall outlays to $3,062 million and transfer the balance of the budget authority into FY 1974, thereby reducing that request by an appropriate amount.

The Fiscal Year 1974 Budget Submission

Even recognising the necessary limitations imposed by a heavily committed nation the FY 74 budget is, to say the least, austere. The agency is requesting a total budget plan, or authority, of $3,107 million, with new appropriations of $3,016 million for a total fiscal outlay of $3,136 million. The $91 million gap between authorised planning and the request for appropriations reflects the applications of unused FY 73 authority held over from December 1972.

The only fair comparison that can be made is to look at each line item in relation to those of previous years, adding depth to the total picture of space expenditure and fiscal trends over the past decade.

Research and Development funds have traditionally followed a roller-coaster path. From 20.7 million in FY 1960 the Apollo Programme caused a jump to $621.4 million in FY 1961 and just two years later had reached $2,968.3 million. The peak year for R&D was FY 1966, carrying a request for $4,575.9 million, with a gradual withdrawl to the $2,288 million figure for FY 1974.

After 12 years of programme planning Apollo is finally deleted from the budget, with Skylab carrying a $581 million request, a decrease of $298 million over last year. The Shuttle R&D request shows a dramatic rise from the $200 million last year to $475 million in the current budget, and advanced missions retain the $2 million provided for in previous years. The overall manned space flight budget rests at $1,057 million, a reduction of more than $100 million over last year. It is interesting to note that the manned space flight portion of the NASA budget exceeded in FY 66 the entire agency request for FY 74 when it stood at $3,249.5 million. Manned space flight is costing the Federal purse only 32% that appropriated eight years ago at the uncorrected dollar value.

The space science portion of the R&D request is reduced by $95 million but is still considerably higher than the $421.8 million for FY 72 and $273.8 million for FY 71. With funds deleted on the Titan III-C and drastically reduced on the Delta the Launch Vehicle Procurement section shows a reduction of $44 million. Physics and Astronomy and Lunar and Planetary programmes lose $51 million between them. Already, the plan to soft-land an instrumented package on the surface of Mars has absorbed $613 million since funding began in the FY 66 budget and it still carries the major portion of Lunar and Planetary Programmes.

Applications suffer a $36 million fall from FY 73, primarily affecting Nimbus 5, the Synchronous Meteorological Satellite, ERTS-B, GEOS-C, and the entire spectrum of communications satellites. This reflects complete abandonment of all advanced communications satellite technology as announced in December, 1972. However, the only two new hardware starts are both in the applications field with $9 million requested for an oceangraphic and air pollution observation satellite (Nimbus G, Nimbus 6 when in orbit), and $1.5 million for a laser-cooperative geodetic satellite (LAGEOS). For the first time Shuttle experiment definition studies receive a separate line item with a request for $4.5 million.

Aeronautics and Space Technology reflects increasing emphasis with a rise from $233 million in FY 73 to $240 million in the currently proposed budget. However, research programmes on nuclear propulsion are deleted from the request for the first time since NASA was formed some 15 years ago.

Tracking and Data Acquisition receives a 0.7% increase over FY 73 and this mirrors concern over the many satellites and spacecraft now made redundant due to the limited communications resources in earlier years. Many vehicles have been prematurely retired because of this.

This completes the R&D portion of the budget, with provision for $10.5 million on new starts versus $12.8 million in the current year and $43.4 million in FY 72.

The construction of Facilities request of $112 million is considerably higher than the current year but if the Shuttle work is extracted from both this and the FY 73 figures the records show a decrease from $50.3 million to $44.8 million. This endorses the view that all unmanned projects are losing ground year by year and an increasing percentage value of the CoF request goes to support manned space flight. Some $67.2 million is allocated for facilities modification or installation at eight NASA field centres.

Research and Programme Management maintains a downward spiral with $707 million requested for FY 74. Once again the Marshall Space Flight Center is hardest hit, suffering a $2.4 million drop in appropriations and a 650 reduction in manpower. The Kennedy Space Center will lose 100 personnel, Johnson will lose 75, Goddard 158, and Ames 30. Langley and Lewis suffer a reduction of 700 between them with Wallops Station and the Flight Research Center remaining virtually unchanged.

NASA manpower levels have dropped from a peak of 33,924 in 1966 to a projected 24,970 in 1974, with a loss of 1,880 in the coming year alone. This represents the second highest yearly loss total since NASA was formed. The impact on industrial manpower has caused severe under-estimation in recent years. By mid-1974 the contractor strength will only just top 100,000 persons and any further cuts in appropriations or programme schedules will degrade this still further.

A controlled optimism can be expressed over the projections for FY 75, however. The President has indicated that he is prepared to accept a $3,235 million NASA budget plan and this does give reasonable grounds for confidence on projects such as the Shuttle and advanced interplanetary missions for the second half of the decade. Undoubtedly NASA has been caught up in an inclement financial environment. It is to be hoped that one quick tightening of the belt at this time will ease pressures for future years. History would lead us to be over-cautious on any such presumption.

FY 74 Schedules

Under the new economy measures several projects have been put back from the FY 73 schedule and others have been cancelled. Manned space flight planning remains constant with the exception of the Shuttle. The first flight to orbit is now planned for early 1979 and even horizontal flights slip to early 1977. The Apollo-Soyuz-Test-Project emerges unscathed with a launch planned for July 1975. It would be hard to envisage a complete absence of any further setbacks, however minor, and NASA faces an 18 month gap in manned space operations following Skylab, and a possible four year gap after the U.S.-Soviet flight in 1975.

From the area of Space Science the observatories receive the heaviest blow. Orbiting Solar Observatory I is now planned for a 1974 launch (J and K were cancelled last year), and the High Energy Astronomical Observatory is cancelled in its present form. The Marshall Center is closely studying the possibility of launching smaller vehicles to pursue similar objectives. The three planetary missions (Mariner-Venus-Mercury, Viking, and Mariner-Jupiter-Saturn) are retained with launches in 1973, 1975, and 1977, involving five spacecraft. Vehicles in the Small Explorer series proceed apace with two planned for 1973, three for 1974, and four for 1975. The only Space Science mission now planned for 1976 is the cooperative solar probe Helios.

The upshot of all this replanning is to provide 9 launches in 1973, including four Skylab flights, 9 in 1974, and 8 in 1975, including the ASTP. If the agency cannot receive sufficient funds to provide new programmes for 1976 it is faced with the prospect of a complete absence of in-house launches. Only two launches are currently scheduled for 1976 and both of those are cooperative ventures. Already discussions have been held regarding the merger of Space Science and Space Applications into the activities of other federal agencies with the National Atmospheric and Oceanic Administration taking over all the meteorological and pollution monitoring roles, the Geological Survey assuming command of Earth resources tasks, and the National Academy of Sciences sponsoring technological investment in scientific satellites. Such a plan can only be seen as a government excuse for burying space activities too deep within the operating budgets of Federal agencies to warrant an anti-space lobby.

The overall situation has worsened considerably in the past two years and many see NASA's ultimate role as custodian of space vehicles such as Shuttle and launch facilities for the payload of other agencies. It is quite likely that when Shuttle development is complete NASA will be relegated to this role unless a viable programme of expanding space capability can once again cause government investment in future technology and allocate reasonable resources accordingly. Until then the agency will be but a shadow of its original inspiration.

This article replaces the final instalment of 'Evolution of the Space Shuttle' by David Baker which will appear in the September issue.

NEXT MONTH

With the Soviet Union attempting further explorations of the planet Mars, the September issue of *Spaceflight* takes a close look at America's progress with the two Viking spacecraft which are intended to soft-land automatic biology laboratories in 1976. There will also be a description of the primary and back-up landing sites.

A CHRONOLOGY OF THE SPACE SHUTTLE

By David Baker

1972 *[Continued from July issue, page 270.*

Aug 7 Grumman, MDC and Lockheed debriefed by NASA as to the reasons for their failure in the Phase Competition.

Aug 9 NASA issues contract number NAS9-14000 to NR Space Division for development of the Shuttle. This provides authority to proceed while a definitive contract is negotiated. Interim value is $12,300,000.

Aug 10 NR announce their plan to issue subcontract RFP's within 90 days.

Aug 14 Boeing names John B. Winch as Space Shuttle Programme Manager in Seattle H.Q.

Aug 15-16 MSFC hold a conference for NASA and its contractors on composite structural materials for Shuttle applications.

Aug 28 MSC awards a contract to Martin Marietta ($226,256) for studies of a cargo handling system in space, called the Attached Manipulator System.

Sep 6 MSFC announces plans to start drop tests into water late 1972 of a 120 in. diameter solid propellent booster simulating a Shuttle booster returning through the atmosphere by parachute.

Sep 7 Shuttle External Tank and Solid Rocket Booster Review held at Marshall Space Flight Center. Amended development schedule.

Sep 7-8 NASA reviews the Shuttle development schedule with contractors at MSFC to orient industry for external propellent tank and solid propellent booster proposals

Schedule for development:

4th Q 72 Programme Requirements Review.
2nd Q 73 RFP on external propellent tank.
3rd Q 73 Orbiter system requirements review.
RFP in solid propellent boosters.
ATP on external tank.
Longlead procurement for fuel tank test articles.
4th Q 73 ATP on boosters.
Begin booster design (33 months).
Begin to fabricate booster.
Pour and cure booster test units (28 months).
1st Q 74 Orbiter preliminary design review.
2nd Q 74 Fuel tank preliminary design review.
Begin to fabricate tank test articles (28 months).
3rd Q 74 Shuttle system preliminary design review.
Booster preliminary design review.
4th Q 74 Long lead procurement for fuel tank No. 1.
2nd Q 75 Fuel tank critical design review.
3rd Q 75 Begin fuel tank fabrication and assembly No. 1 (23 months).
Begin test programme on fuel tank test articles (26 months).
Begin booster test firings (18 months).
Long lead procurement for vertical flight boosters.
4th Q 75 Begin test programme on booster test units (25 months).
1st Q 76 Orbiter critical design review.
Booster critical design review.
Begin to fabricate, pour and cure vertical flight boosters (22 months).
4th Q 76 First horizontal flight of orbiter.
1st Q 77 Long lead procurement for production boosters.
2nd Q 77 Begin to fabricate, pour and cure production boosters (11 months).
Deliver fuel tank No. 1 to KSC
4th Q 77 Begin production of fuel tanks (6X1978; 12 x 1979; 24 x 1980)
1st Q 78 First manned orbital flight of Shuttle.

Sep 17 NR announces subcontracts to Grumman and MDC (worth $8 million and $4 million in the current fiscal year respectively) for specialised engineering support services.

Sep 28 Boeing transfers its Shuttle team to the Micbond Assembly Facility.

Oct 2 NR announce 6 year contract with American Airlines to provide engineering support for Shuttle maintenance and ground operations.

Oct 5 NASA Administrator James B. Fletcher issues detailed report on the choice of NR for Shuttle development and reasons for rejecting MDC, Grumman and Lockheed.

Oct 6 MSC award 14 month contract ($139,500) to the Pillsbury Company for an analysis of food requirements for orbiter crews.

Oct 31 Arnold W. Frutkin announces a NASA decision that all subcontracting on the Shuttle orbiter will be restricted to US companies.

Oct NR Space Division establish a development baseline for the Shuttle. The orbiter will be 125 ft. 9 in. long with a wing span of 83 ft. 9.7 in. weighing 170,000 lb. empty and 238,093 lb. at launch. Each solid propellent booster will be 184 ft. 9 in. long with a diameter of 13 ft. weighing 212 lb. empty and 1.627 million lb. with propellent producing a per unit thrust of 4,130,000 lb. at launch. The external propellent tank for the orbiter is 182 ft. long, 26 ft. 6 in. in diameter and fully loaded weighs 1,782,000 lb. At launch the configuration stands 202 ft. 3 in. high, weighs 5,410,000 lb. and with the three 470,000 lb. thrust orbiter engines assisting lift-off produces a thrust of 9,385,000 lb.

Nov 1 OMSF begin negotiations to permit NR to sub-

contract for the orbiter tail assembly, elevons, cargo bay doors and undercarriage.

Nov 2 NR awards 21 month contract to Intermetrics Incorporated for an advanced computer programming language for the Shuttle.

Nov 7 NR issues RFP's for orbiter's wing, centre fuselage, and vertical tail. Proposals to be submitted by 10 Jan. 1973, 24 Jan 1973 and 15 Dec, respectively.

Nov 13 NASA holds programme requirements review with MSC and NR teams. Several changes in the baseline configuration are proposed. The abort propulsion system is omitted and the SRM's are increased in diameter to 13 ft. 6 in. producing a unit thrust of 4,150,000 lb. for a lift-off thrust of all propulsion systems of 9,515,000 lb. Gross lift-off weight is now 5,534,000 lb.

NASA holds programme requirements review configuration baseline briefing. Abort propulsion system is deleted in favour of TVC on solid boosters, and orbital manoeuvring system thrust is increased to 6,000 lb. per unit from the previous 5,000 lb. Main undercarriage track is increased by 20 in. External tank length is increased to 189 ft. 9 in. diameter reduced to 25 ft. 4 in. launch weight is decreased to 1,732,000 lb. inert weight to 82,000 lb. SRM's are increased in length to 191 ft. 8 in. diameter increased to 13 ft. 6 in. launch weight per unit to 1,638,000 lb. inert weight to 232,000 lb. and thrust per unit reduced to 4 million lb. The total configuration now stands 214 ft. 4 in. tall and weighs 5,246,000 lb. at launch, with a total thrust of 9,125,000 lb.

Nov 14 Programme requirements review data screened, documented and approved.

Nov 21-22 Five-man NR Space Division team brief prospective subcontractors at Long Beach, California, in first of three regional symposia.

Nov 27 NR Space Division establish baseline development schedule as follows:-

Aug. 9, 1972	Orbiter authorisation to proceed.
Nov. 13, 1972	Programme Requirements Review.
Apr. 1, 1973	Issue RFP's for solid propellent boosters.
Jul. 12, 1973	Shuttle System Requirements Review.
Aug. 1, 1973	External tank authorisation to proceed.
Nov. 1, 1973	SRM authorisation to proceed.
Apr. 1, 1973	Preliminary design review of external tank. Begin fabrication of test articles.
Jul. 1, 1974	SRM preliminary design review.
Jul. 8, 1974	Shuttle system preliminary design review.
May 1, 1975	External tank critical design review.
Jul. 1, 1975	Begin fabrication of external tank No. 1.
Jan. 1, 1976	Begin fabrication of SRM No. 1.
Feb. 1, 1976	Orbiter/SRM critical design review.
Dec. 1, 1976	First orbiter horizontal flight.
Jun. 1, 1977	Begin full scale SRM fabrication (1/MTH).
	External tank No. 1 on deck at Kennedy Space Center.
Nov. 1, 1977	SRM's for first vertical flight on deck at KSC.
Mar. 1, 1978	First manned orbital flight.

Nov 27 Second regional subcontractor briefing held at Fort Worth, Dallas.

Nov 30 MSC issue an RFP for a closed-circuit Colour TV System (CTS) to be used in external image simulations assisting crew training. Bids due by 11 Dec.

Nov 30-Dec 1 Third NR Space Division regional subcontractor briefing held at Boston.

Dec NASA approves space shuttle main engine schedule:-

Feb. 29, 1974	Preburner tests.
May 31, 1974	First thrust chamber tests.
Aug. 1, 1974	First high pressure turbopump tests.
Dec. 7, 1974	First integrated subsystems test.
Mar. 1, 1975	First engine system test at Michoud Test Facility.
Jun. 15, 1976	Delivery of Test Engine.
Feb. 29, 1976	Critical design review.
Oct. 15, 1977	Delivery of first engine.

1973

Jan. 9 Johnson Space Center (JSC, formerly Manned Spacecraft Center) extends contract with Bernhard Knust Inc., for shuttle wind tunnel model fabrication.

Jan. 26 JSC awards a $1,375,484 contract to MIT for GNS technical support. Contract expires Aug. 3, 1974.

Jan NASA requests $546.7 million for shuttle development in FY1974, confirming a first manned horizontal flight in 1977 and first manned orbital flight in Dec. 1978.

Jan NASA approves Rockwell's 'lightweight' shuttle. The orbiter has double delta ($75^\circ/45^\circ$) 2,100 ft^2 wing, 78 ft. in span with a gross lift-off weight of 150,000 lb. Orbiter length is retained at 125 ft. External tank has dry weight of 74,000 lb., propellent weight of 1.56 million lb, length of 165 ft. 7 in, diameter of 27 ft. Boosters each to weigh 1.13 million lb., length 144 ft. 3 in, diameter 11 ft. 9 in. (141 in.). Total system 193 ft. 3 in. long, 78 ft. in. span with gross liftoff weight 4.101 million lb. (see Nov. 13, 1972).

Feb. 5 MSFC begins solid rocket motor water impact tests at Long Beach Naval Shipyard. Tow tests to be conducted off KSC. Refurbishment of boosters accounts for 47% of $10.5 million launch cost.

[Continued on page 319

ARE SATELLITES REALLY NEEDED FOR EUROPEAN EDUCATION?*

By Dr. J. L. Jankovich

Introduction

We have heard excellent papers on the problems facing education and on promising approaches to their solution. Do these solutions call for satellites? And if yes, for what types, and when?

Let us attempt to answer these questions in a series of steps: Firstly, by looking briefly at the technology needs of education in general, and then, at the requirements for telecommunications in particular. Next, by assessing the needs which cannot be met by existing facilities and which call for satellites. Then, by considering the implications of our findings for educators, politicians, technical agencies and industry. And finally, by trying to envisage what it all means for each of us.

Growing Gap

Educational needs are growing exponentially: the number of children reaching school age increases gradually in step with the population growth; then the number of age groups participating in education also increases as the result of the continuous lifelong education concept; finally, more subjects should be taught, and on more levels, then before because of the differentiation of our lives.

In contrast, educational funds can grow only linearly, i.e. more or less as a fixed percentage of the national budgets. The gap between educational needs and funds is therefore growing at an accelerating rate. To bridge the growing gap, we have to apply leverages through our other resources: our brains and technologies.

Our potential brainware contribution includes planning, organization, orientation and development of didactics, and the selection of the most appropriate technical aids. As for educational technologies, we see (pp. 95-113) that radio and TV broadcasts are only two of the many feasible alternatives. Educators also have at their disposal video and audio cassettes, closed-circuit TV, computer-assisted instruction, to name but a few.

Whatever particular technology is chosen for a given application, its effective functioning depends on the smooth operation of a far-reaching network of teachers, technicians, libraries, studios, and a lot of electronics. The unit cost of such an extensive operation may decrease substantially when there are many participants, possibly on continental scale.

Systems Approach

This point brings us to the European telecommunication facilities needed in support of the envisaged educational technology applications. Telecommunications of continental dimensions should be planned a decade or more ahead before actual full operations can really commence.

How can we now formulate the telecommunication needs of many possible educational technology aids for say 15 years ahead when we are not certain yet which particular aid we shall actually choose?

The methods of the systems approach and long-range planning supply the answer. These methods, long used in modern business and applied to education perhaps for the first time in a Council of Europe programme [1], were further refined as part of a more recent study effort [2].

Instead of retaining all the details of every possible educational technology application, we identify the types and groups of sources and users of the various educational services, their interconnections, the information flow, etc. By considering these categories of network models, our subsequent discussions are detached from specific application details and have a rather general validity in the entire field of technology aids to education.

These considerations reveal that the envisaged educational technology applications require only 3 basic types of telecommunication facilities:

1. A source network of educational information, i.e. a two-way flow of information;
2. A broadcast service to the public in general, i.e. a one-way information flow, and
3. A special service on select individual basis, i.e. with feedback to the information source.

The essence of this finding is that these three facility types, if each of sufficient capacity, can support practically all the various educational services, including those which are conceivable but not investigated in detail in our study.

The listed telecommunication requirements are derived from the interface technology needs of potential target audiences, without regard to the transmission medium. Thus, they appear generally valid for years to come, no matter what new transmission technology innovations materialize. In fact, the above classification holds even if our considerations include regular mail service, as a means of communication, too. The last observation is relevant to the assessment of the impact video-cassettes may have on our further investigations.

Quantum Jump

There are many fields where the transmission delay resulting from cassette mailing is unimportant: in the dissemination of basic information, entertainment, etc. However, the real value of the stimulus provided by the availability of instantaneous communication and feedback remains to be assessed. The numerical requirements for telecommunication capacity are impressive [2]. As of 1980, for European higher education alone, the necessary *source network* capacity is estimated as equivalent to about 600 or 1000 one-way TV channels, depending on whether or not a large-scale use of video-cassettes is also assumed; the 1985 figures may be 60% higher.

The 1980 estimate of required capacity for higher educational *broadcast service* alone calls for 2 to 4 full-time TV programmes; the 1985 projections indicate the need for 6 to 10 such programmes.

The basic reason for this large demand is the fact that the envisaged educational applications represent new services: a sort of quantum jump with respect to the more traditional ways of education. As a consequence, the associated need for telecommunication capacity also represents something out of line with the smooth projections based on standard telephone, radio and TV usage only which serve as customary basis for PTT planning.

The Case for Satellites

Let us now look briefly at the alternatives which may be available to meet the formulated telecommunication requirements.

First, technically, we are interested whether or not a given

**Paper presented at the Symposium on 'Space Communications Systems for Education Purposes' of the British Interplanetary Society, University of Southampton, 21 Sep. 1972.*

transmission medium can provide the required facilities, i.e. the specified network configuration, capacity, switching, area coverage or selective addressing, etc. Second, economically, we are concerned with the overall relative costs of alternatives, e.g. from the viewpoint of an intergovernmental organization operating on European scale. The eventual cost-sharing among countries and governmental departments does not now enter our investigations. Thus, for each satellite application, we include the full cost of satellite and launcher development, Earth station procurement, etc. As for our *educational source network,* the existing Eurovision network presses for first consideration. However, even the full Eurovision capacity amounts only to a fraction of what may be needed by higher education alone in the 1980-85 period; hence, its extension, if any, shall involve substantial new installations.

The cost estimates of such a large terrestrial network are compared with the expenses of renting or building satellite facilities in Fig. 1. The 3 alternatives are evaluated in terms of the annual cost it takes for each to provide the equivalent source network capacity of 180 one-way TV channels. For the terrestrial network cost, we consider only the links but not the switching centres. In the case of rented INTELSAT-type satellite facilities, no correction is made for the cost of the inevitable hook-up links and the quoted figures apply, strictly speaking, only between existing standard Earth terminals. For the special-purpose distribution-satellite configuration, we have included the full development cost and procurement of the launcher, satellites, and 500 medium-size Earth stations, with capital amortization over a lifetime of 15 years, replacement and maintenance; also, demand-assignment of the channels is assumed.

Break-even Point

The resulting annual system cost is shown in Fig. 1 as a function of the equivalent terrestrial length of the average link. The cost of the satellite-based configurations is independent of the terrestrial distance of the Earth terminals: a fact illustrated by the horizontal lines of the diagram.

The cost of the terrestrial system is a function of the average link length and capacity, as shown by the two slopes in Fig. 1. The diagram reveals that there is a certain distance for each set of configurations below which terrestrial communication is cheaper, and beyond which satellite communication is more economical. The exact value of this crossover depends on the underlying assumptions. For instance, for a network with 500 terminals, the Europa 4 satellite operation is cheaper than terrestrial for links of 780 km length or more, etc.

The break-even distance shrinks substantially when we assume that the same Europa 4 launchers also will be used for other applications and less than the full development cost is charged to our single educational network service.

As for *educational broadcasting services,* fundamental technical considerations limit the number of TV programmes which can simultaneously cover a major geographic area. Within the frequency range of present standard home receivers and with direct broadcasting, the maximum number of programmes is about three. If all these programmes could be put to full-time educational use, they would barely meet the projected needs of higher education alone in 1980. However, as a knowledgeable expert, Monsieur R. Lefranc, points out [2]:

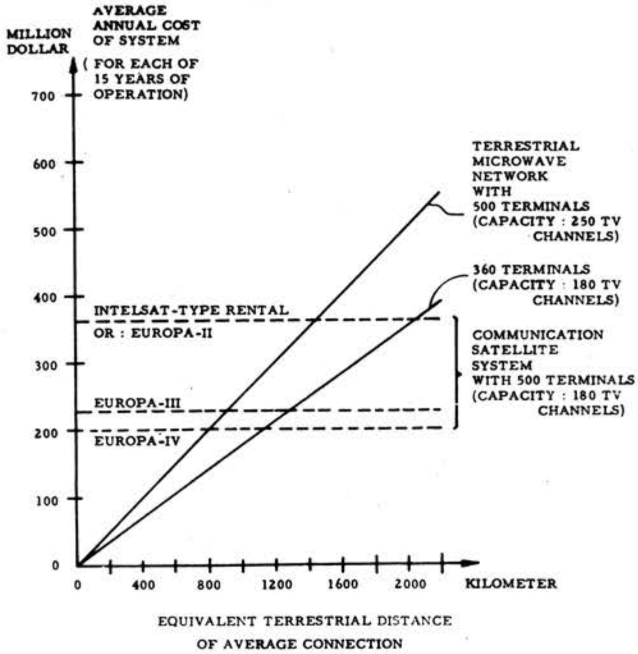


Fig. 1. Relative annual cost of terrestrial and communication satellite systems.

'In several European countries, educational radio and TV broadcasts cannot obtain an increase in their programme hours. In France, the university and post-graduate TV broadcasting cannot use the advantageous evening and weekend hours; the creation of a third broadcasting chain, not of educational nature, will not solve the problem. A similar situation can be noticed in Great Britain where the Open University cannot use more than a few hours of TV a week. The analysis of the situation in Germany also leads to the need for increasing the number of facilities'.

New Facilities are Needed

Additional programmes can be broadcast only in frequency bands around 12 GHz for which entirely new broadcaster and receiver facilities are needed. In our comparison of feasible alternatives we therefore assume that all the novel broadcasting schemes will operate at super-high frequencies and require new equipment.

The costs of terrestrial and satellite broadcasting arrangements are compared in Table 1 for a practically complete coverage of Europe by educational programmes. The terrestrial system includes an extensive Europe-wide programme distribution network, at least partially along new routes. The satellite schemes also include the full cost of developing, manufacturing, and procuring the launchers and spacecraft for 15 years of lifetime.

Individual Programmes by European Satellites?

The semi-direct satellite broadcasting arrangement provides not only the lowest cost per programme channel but, also, exhibits the significant flexibility – not found in the direct satellite broadcasting system – of enabling separate regional or national programme broadcasts simultaneously.

TABLE 1. Initial cost of Alternative TV Broadcasting Techniques for European Coverage.

	Technique	Total Cost (in million dollars)	Cost per Prog. (in million dollars)
Terrestrial	New 12-GHz broadcasters with microwave link inter-connections	7100	3550
	Direct broadcast at 12 GHz from single 2-ton satellite	5892	2946
*Satellites**	Semi-direct broadcast at 12 GHz from 12 satellites of 500 kg each;† wired distribution from community centres	6124	1531

Notes: * Costs quoted for satellite systems include development and manufacture of launch and satellite in sufficient numbers for 15 years of operation.

† Each also is capable of providing a national or regional coverage with one or more of the available four programmes.

The community reception in the semi-direct system does not represent a serious limitation if it is equipped to supply all the available programmes. On the contrary, the centre can provide a greater variety of service than possible in a direct system. As for the establishment of our *special educational services,* involving two-way audio-visual communication, new facilities will be needed and the community centres of semi-direct TV broadcast reception may provide a useful start. When properly equipped, the community centres could link the individual homes or working places with the electronic audio-visual-data centre of nearby educational institutes. Then through the institute's connection with other sources of educational information – through terrestrial and satellite links – the individual student or professional could get in audio-visual-data contact with the rest of his professional world without leaving his home or working place. A possible arrangement of these elements is shown in Fig. 2.

This facility is not a satellite-based service of its own. It is included here because it is needed for important educational applications and the suggested satellite systems do provide the basis for its realization. However, as of now, no PTT plans are known to set up such service or to consider its telecommunication needs in the foreseeable future.

Beyond Planned Capabilities

The essence of what we have seen so far is the following:

(a) The solution of educational problems calls for telecommunication facilities of types and dimensions which are far beyond the capabilities of existing European networks or their extensions as now envisaged by the cognizant authorities.

(b) The telecommunication facilities necessary for education appear much cheaper when supported by satellites; even by very cautious estimates, the annual savings on European scale may amount to hundreds of millions of dollars.

(c) Such satellite services will become available in the early 1980s only if pertinent initiatives and decisions are taken *now.*

Do Nothing?

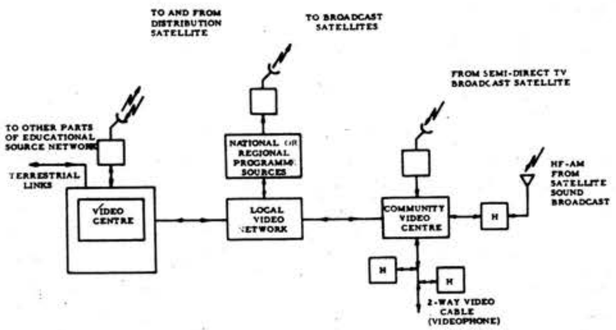
The educationists have the choice of two alternative attitudes as a starting point.

1. One is for the educationists to adopt a passive stance: do nothing now, wait until new technical developments take place at the initiatives of others, and then try to make do with whatever facilities are left over. This is, in fact, what has happened to standard radio and TV broadcasting – with the results succinctly summarized above in Monsieur Lefranc's remark.
2. The other alternative consists of active educationist participation in *causing the changes desired for education.* This stance involves:

   Definition of our long-range goals and needs.
   Survey of related possible technical developments in advance.
   Choice of technology most conducive to our specified goals.
   Promotion of actual development of chosen technology by motivating those who are in charge of the technology.

The feasibility of the active attitude is illustrated – in a very modest way – by the related efforts of the Council of Europe [1, 2].

The forward-looking attitude is, of course, tied to *educational research* on the central practical question: which technology should be chosen as the best educational aid in a given situation? The answer depends on the involved costs, meaning not only the transmission facilities we have just discussed but, also, the preparation and updating of the transmitted educational programmes. The involved costs can realistically be evaluated only on the basis of achievements.



Educational video network.

How do we specify educational achievement? The meaningful basis of comparison seems to be in terms of the goals set for education. Confucius in 479 B.C. complained that, 'teachers don't know objectives, and almost no one would specify what one should know or be able to do'. The situation has not greatly changed. Thus, a part of the needed research should turn toward this most basic question of educational objectives. The answer is more urgent than ever because of its direct relevance to the emergence of a new European society.

Satellites to Change Society

The new technologies, and the satellites *par excellence,* are not just improved tools for the better performing of our age-old tasks: they also enable entirely new kinds of services which, in turn, bring about social changes as well.

To begin, the new technologies imply a change in the role of the teacher. In practice, every good teacher is overburdened and anything that gives him the opportunity to make more contact with his pupils is clearly desirable. Thus, the case emerges for as powerful technology assistance to the teacher as possible. This leads, in turn, to a wide-based co-operation in the planning, development, and use of the new methods since no single country alone can hope to produce all the educational programmes needed for all of its schools, subject matters, grades, etc., in time. Also, most of these applications become more economical if the expensive central equipment, computers, studios, etc. are shared by many through terrestrial and satellite communications. The co-operation often appears easier along disciplinary lines, even if they happen to cross state borders, than along traditional national communication hierarchies.

Now, we know that society is a group of people in communication. What is more, communication is *the* controlling influence in their connections. Thus, by setting up and using new means of communication, we also affect the subsequent development of community organizations of society. Satellites enable us to establish communication between practically any points, or any groups of points, either directly or through intermediaries as desired. By communication satellites we obtain a new degree of freedom in the social dimension and hence, the technology aids to education pave the way toward new types of social association and development on a European scale.

The continental broadcasting by satellites of educational programmes, for instance, provides a ready opportunity to promote the formation and strengthening of common European values and viewpoints.

What Sort of Life Do We Want?

Political implications arise as a consequence of educational technologies. At the root of these is the fact that education is not an isolated institution of our society: it is surrounded by such other activity fields as commerce and industry, science and technology, politics and arts, all of which are changing rapidly in our times. In other words, the educational objectives – which should guide our pertinent technology efforts – can be defined only in relation to other activity fields of our society. In essence, the basic problem appears as the specification of the sort of life and society we want for ourselves in 10 or 20 years.

The problem can be separated into 2 broad categories:

1. Questions to be settled by the public and its elected officials, such as what sort of life we want in the future, etc., i.e. questions concerned with the formulation of the goals of our society, and

2. Questions concerned with the ways of achieving those goals, e.g., what are the scientific facts, whether the goals are feasible and at what cost, what are the best ways of approaching the goals, etc., [3].

Participants of our Conference may well contribute to both categories: first, as citizens, and Europeans, to the formulation of national and European goals; second, as knowledgeable professionals, to the competent survey of alternative approaches to the goals, possibly through the more conscious application of educational technologies and satellites.

Synthesis: The Key

The key tool for the leverage operation, needed to close the gap between educational needs and funds, may be stated as synthesis: we have to aim at synthesizing the technology configurations which will best serve our educational and other objectives on European and national levels. The question of an independent European development of satellites and launchers should, therefore, be investigated in the above perspective, too.

Not all the elements required for a complete synthesis are fully available yet. For instance, extensive research is needed on the social effects of educational and communication technologies. Money for the projects will eventually be allocated by the governments and their main motivation must come from the ultimate users: in our case, the educationists. Only the educationists can formulate their needs for technology and put those needs with due emphasis before the policymakers. It will then be up to the governments to allocate the funds under the appropriate headings: education, PTT, science and technology, research, etc.

The research and investigation associated with the synthesis of educational technology applications should be firmly funded as an important item of the national budgets – perhaps as a fixed percentage of the total educational or national research expenditures. Similarly, a part of the national educational research funds could be earmarked for related participation in European co-operative projects, e.g. the tentative specification of educational technologies and telecommunication facilities on continental scale .

New Marketing Methods

Industry and the concerned technical agencies must, in their own best interest, aim at helping the educationists in the formulation of alternative approaches to the desired goals by a fair presentation of feasible technical solutions, their relative merits and costs. Industry may want to develop new marketing and planning methods to match the emerging unique business opportunity. Industry managers must bear in mind the following rather particular features of the educational technology market:

(a) Long-range planning and procurement, i.e. extending up to a decade and beyond;
(b) Great variety and huge amount of needed equipment, with an order-of-magnitude value that is comparable to several percent of the total national budgets;
(c) Most of the needed products do not yet exist, except

their components and the know-how of their assembly;
(d) No customer or applicable budget item can yet be identified specifically since, as of now, there is no organized 'educational customer' on a continental scale; and
(e) User is not technically minded, and the potential supplier industry is not educationally minded.

The possible marketing approaches of industry may therefore include the following steps:

1. *Long-range thinking and planning in step with educationists.*
2. *Willingness to invest in learning about a new field, and helping the customer to learn about the technical possibilities, i.e. to promote the formation of the customer.*
3. *Forming special long-range marketing groups, detached from the immediate business concern, etc.*

It Is All Up To Us

Electronic technologies, including satellites, promise effective help to educational problems which cannot be solved by traditional methods alone. Whether or not satellites are indeed needed for education, depends mainly on the educationists. As Mr. M. Edmundson put it very aptly, the basic question is whether or not the educationists will be imaginative and bold enough to take a long-term look at their objectives and needs, express them to their governments, and insist upon them in face of competition.

To formulate such a stance in a co-ordinated way and on European scale, it will probably help the educationists if they obtain the pertinent facts to support their arguments with the governments in a coherent fashion, e.g. from the envisaged follow-up programme of the Council of Europe; and have a forum where they could discuss experience, exchange views, and prepare co-operative efforts.

The present Conference will provide effective help to such a development by the formulation of pertinent proposals and by putting them before the cognizant authorities. However, there is a popular illusion that merely because someone draws up a persuasive plan, somebody – somehow – will implement it. Nothing can be farther from the truth. None of the envisaged applications of technology will ever materialize, unless the cognizant persons take a decision now.

Thus, if our present meeting can bring about a positive follow-up action, we may safely say that satellites are really needed for European education and culture.

REFERENCES

1. J. L. Jankovich, 'Technological Change in Europe in the Next 20 Years as Relevant to Satellite Application for Education and Culture', document CCC/ACV/69/41; Council of Europe, Strasbourg, 2 June 1969.
2. J. L. Jankovich, 'Satellite Communication Services for Education in Europe', Final Report; Council for Cultural Co-operation, Council of Europe, Strasbourg, April 1971.
3. A. Kantrowitz, 'Proposal for an Institution for Scientific Judgement', *Astronautics & Aeronautics*, **10**, 5, p.5, May 1972.

A CHRONOLOGY OF THE SPACE SHUTTLE *Continued from page 314]*

Mar. 7 Elements of a preliminary bioresearch simulator arrive at MSFC for shuttle payload design. The payload carrier simulator is 48 ft. long, 14 ft. in diameter.

Mar. 15 JSC issues RFP for hydraulic actuator test models. Proposals to be submitted by Apl. 2, 1973 for a 12-month contract.

Mar. 29 Rockwell International Corp., (formerly North American Rockwell) awards four major orbiter subcontracts: Fairchild Republic Div., of Fairchild Industries Inc., $13 million for vertical tail unit of modified swept triangular shape, 26 ft. high, 22 ft. long at fuselage interface; Grumman Aerospace Corp., $40 million for double delta wing weighing 14,000 lb., 62 ft. long at fuselage, 34 ft. to the tip; Convair Aerospace Div., of General Dynamics, $40 million for 12,000 lb, mid-fuselage 62 ft. long, 17 ft.wide, 13 ft. high forming payload bay area 60 ft. long, 15 ft. diameter; McDonnell Douglas Astronautics Co., $50 million for orbital manoeuvring system comprising two 6,000 lb. engines, propellent guaging pressurisation and distribution subsystems, and two pod covers. RI reaffirm plan for 10,000 subcontractors.

Apl. 2 NASA issues RFP to McDonnell Douglas, Boeing and Martin Marietta for external tank design, development and production. The ET retro motor is deleted in favour of pre-orbit release and thrust to orbit with oms. ET is to be 158 ft. long, 27 ft. in diameter carrying 1.5 million lb. of propellent (Lox/LH_2). Procurement contract will authorise 3 test articles, and 6 flight units, the last delivered early in 1979. Second phase procurement for 54 units delivered 1979-81, third phase for 385 units 1981-88. Contract to be awarded August.

Apl. 2 NASA indicates possible flight schedule: 1978/6 (flights), 1979/15, 1980/24, 1981/32, 1982/40, 1983 to 1987/60 per year, 1988/28 for a total of 445 in 11 years. Potential ET bidders to look at DDT & E costs for a 242 flight programme over the 11 years with a 30 flight per year maximum in 1983-88.

Apl. 16 NASA signs a definitive contract with Rockwell International Corp., for shuttle, superseding letter contract of Aug. 9, 1972. The $477,400, 000 contract expires Aug. 3, 1974, to be replaced with a second increment covering design, development, test, evaluation and delivery of two orbiters.

Apl. 18 Astronaut Fred Haise is named Technical Assistant to the Manager, Orbiter Project Office, JSC.

VIEWPOINT

'Spaceflight'

The *New Frontiers* articles in December *Spaceflight* were particularly interesting, the 'Antifacts' one especially. One point though – if the civilised beings that visited us in the past had any sort of 'empire' the chances of visits must be greater – from their successful colony worlds as well as from their home planet.

A. J. UNSWORTH

Our *Academic Radioclub – Laik,* of which I am Executive Secretary, was the *first* one to qualify for the Oscar 6 diploma,in case somebody has the intention of writing about the satellite in *Spaceflight.* We would like to be known! I have seen some Ham's signatures in your articles and I would like to see more articles about amateur radio satellites and rockets in *Spaceflight* or the *JBIS.*

INGE TORKILDSEN

I am sure an article on the Mission Control Computer and onboard computer used on the Apollo missions would be of great interest to many members.

S. MURPHY

(Readers interested in this subject will be pleased to see that the Society is planning a Main Meeting on 'Computer Techniques in Space Projects', for 25th September 1973 – Ed.).

I was wondering if you would do a complete photographic and essay review on the past complete series of Apollo flights. I think it would be of great interest and a fitting tribute to the end of a great programme.

WILLIAM C. UPTON

In my humble view the Society devotes far too much space (magazine-wise) to the transportation methods used, and to be used in *Spaceflight,* and not enough to the actual planets themselves.

F. DANIELS

I have been very pleased with J. S. Griffith's contributions to *Spaceflight,* and I am delighted to see they have been promoted to the *JBIS* and made a little more formal. His astronomical notebook is just what I need to keep me up-to-date with what is happening. If he needs more space, please give it to him.

DAVID DAVIES

Could we please have more articles dealing with events somewhere in between the near future (exploration of the Moon and Mars, etc.) and the far future (the interstellar age?) I refer to voyages to the mysterious outer planets of the Solar System and their extensive moon systems. Uranus and Neptune in particular seem to have been left out in the cold.

P. J. MARSHALL

A friend of mine has just shown me copies of your two publications *Spaceflight* and *JBIS,* and I was really amazed by their quality.

My interest in space technology has lasted for more than 10 years and I understand now that I have missed two of the most informative and exclusive space publications in the world.

GORM B. RASMUSSEN

I am familiar with *Spaceflight* and the *JBIS* through our company library. Frankly, the quality and content of your publications, plus the open-minded approach to futuristic ideas found therein attracted me to your organization.

JOHN F. SCHUESSLER

As a 'Space Buff' of many decades, your periodical is one of my most looked forward to moments of a month................

I would like to see an occasional 'colour' photograph.

HERBERT N. WOLFE

As a matter of interest, I take *Spaceflight* myself for its 'newsey' approach. I must confess to much glee over some of the letters... .....keep those zany ones flowing.

JACK S. JACOBS

While reading *Spaceflight* I noticed several obvious mistakes which occured in the main articles..........

The second area of error is in the Correspondence section, specifically the letter in p.158 on Matter Transmitters. I suspect that the problem here is that *the original letter was handwritten,* and difficulties arose over transcribing it for printing. This could be avoided by requesting that all letters for publication (as distinct from other correspondence, which no doubt burdens your day, as this letter must be doing) must be typed, or at least written very clearly.

Dr. A. R. MARTIN

(It certainly would be very helpful if letters could be typewritten, or at least written in a very clear fashion. It would be particularly helpful,too, if correspondents always wrote their signatures legibly! -Ed.).

Keen Type – 1

It is some 15 years since I first joined the British Interplanetary Society and 14 years since this association unfortunately lapsed....

HAROLD H. FULTON

Keen Type – 2

Please forgive this extreme delay in forwarding my 1973 dues............. I finally dug out the ditch for a water line in a neighbour's house and replaced the pipe, thereby earning the necessary $20.00 which I enclose. Please understand my position...........

JOHN K. PRENTICE

Thanks, pal!

I have no worthwhile complaints to make about the Society, so I will refrain.

NIC R. S. CLOUSTON

Postal Trouble

In the 20 years I've been a member of the BIS, publication delivery time has increased from 3 weeks to 2-3 months.

B. P. MARTIN

(Numerous complaints have been received during the last few months from members in America complaining about slow delivery times. The reason for an enormous increase in the transit period is not known to us, nor have we been able to obtain any information on the matter, e.g. whether the delay took place in the UK, in distribution in America, or if the cargo ship carrying the mail was routed via Hong Kong! – Ed.).

Natural Modesty!

One of the things which first struck me when I joined the Society was the friendliness of the officials.

Dr. M. D. JONES

(Not always! –Ed.).

Limited by Guarantee

I note that the Society is a company limited by guarantee and I am interested to know what obligations, if any, this places upon the members, especially in the unlikely event of the Society being wound up in a state of insolvency. Would members be responsible for meeting debts of the Society?

ANTHONY S. PUREY

(This means that every member undertakes to contribute up to £1 to pay for the Society's debts, if it is unable to meet these from its own resources. –Ed).

The Editor is always interested in receiving items of correspondence for publication. Letters should be brief.

Spaceflight

Spaceflight is published monthly by the British Interplanetary Society, and is issued free to members.

Full particulars of membership may be obtained from the Executive Secretary at the Society's offices at 12 Bessborough Gardens, London, S.W.1: telephone 01-828 9371.

Correspondence and manuscripts intended for publication should be addressed to the Editor at 12 Bessborough Gardens, London, S.W.1.

Opinions in signed articles are those of contributors, and do not necessarily reflect the views of the Editor or the Council of the British Interplanetary Society, unless such is expressly stated to be the case.

MAIN MEETING

Theme **Computer Techniques in Space Projects**

To be held in the Architecture Lecture Theatre, University College, Gower Street, London, W.C.1, on **25 September 1973** *(All day).*

1. On-board Computers & Data Processing.
2. Ground Computers & Space Data Processing.

Offers of Papers are invited relating to:–

(a) Scientific Satellites.
(b) Satellites for Communications, Meteorology, Earth Resources and Applications Satellites.
(c) Manned Spacecraft.
(d) Launch Vehicles.

Further details are available from the Executive Secretary.

FILM SHOW

Programme to be announced in the next issue.

To be held in the Botany Lecture Theatre, University College, Gower Street, London, W.C.1., on **27 September 1973,** 6.30 - 8 p.m.

No admission tickets are necessary. Members may introduce guests.

MAIN MEETING

Theme **Sounding Rockets and Experimental Results – 3**

To be held in the Architecture Lecture Theatre, University College, Gower Street, London, W.C.1, on **27 September 1973** *(All day).*

Offers of Papers are invited.

Further details are available from the Executive Secretary.

24TH IAF CONGRESS

To be held in Baku, USSR, from **8 - 13 October 1973.**

Further details are available from IAF Secretariat, 250 Rue Saint-Jacques, 75005 Paris, France.

TRENT VALLEY FILM SHOW

To be held in the Adult Education Centre, St. Helen's House, King Street, Derby on **26 October 1973** at 7.30 p.m.

The programme will include the following:–

(a) Skylab.
(b) Man in Space – the Second Decade.

Further details of this and other meetings can be obtained from any of the following:–

Branch Secretary.	Mr. H. R. Curtis, 54 Eton Road, Burton-on-Trent, Staffs; DE14 2SW.
Asst. Branch Secretary	Mr. N. T. Wilson-Smith, 49, Robinscroft Rd., Allestree, Derby, DE3 2FQ.
Nottingham Representative	Mr. B. Holbrook, 244 Charlbury Rd., Wollaton, Nottingham.
Derby Representative	Mr. R. D. Law, 84, Bramfield Avenue, Derby.

SPACE STUDY MEETING

The 11th Space Study Meeting will be held in the Kent Room, Caxton Hall, Caxton Street, S.W.1, on **31 October 1973,** from 6.30 - 8 p.m.

The Programme will feature a talk by J. Ashworth on 'The Use of Satellites for Press Purposes'.

FILM SHOW

To be held in the Botany Lecture Theatre, University College, Gower Street, London, W.C.1, on **14 Nov 1973,** 6.30 - 8.30 p.m.

The programme will include the following:–

(a) Lunokhod 1
(b) Welcome Moonstone
(c) Journey to the Sea of Rains
(d) Apollo 17: On the Shoulders of Giants.

No admission tickets are needed. Members may introduce guests.

SPACE STUDY MEETING

The 12th Space Study Meeting will be held in the Kent Room, Caxton Hall, Caxton Street, London, S.W.1, on **28 Nov 1973,** 6.30 - 8 p.m.

The meeting will feature a talk by Dr. A. R. Martin on 'Electric Propulsion for Advanced Space Missions'.

No admission tickets are needed. Members may introduce guests.

TRENT VALLEY LECTURE

Title **Skylab, Space Stations and Space Shuttles**

by P. J. Parker

To be held at Burton-on-Trent Technical College, Lichfield Street, Burton-on-Trent, Staffs on **15 February 1974** at 7.30 p.m.

Further meetings are being arranged. Further information can be obtained from any of the Branch representatives listed under the meeting dated **26 October 1973.**

LECTURE

Title **Extraterrestrial Intelligence** by Prof. Carl Sagan.

To be held in the Lecture Theatre of the Royal Society of Arts, John Adam Street, London, W.C.2, on **3 May 1974,** 6.30 - 8. p.m.

No admission tickets are necessary. Members may introduce guests.

REPEAT FILM SHOW

A Film Show on the theme of 'The Best of Apollo' will be held in the Botany Lecture Theatre, University College, Gower Street, London W.C.1, on **29 May 1974,** from 6.30 - 8.30 p.m, to provide another opportunity for seeing again some of the spectacular films recording the Apollo Missions.

The Programme will be as follows:–

(a) Debrief: Apollo 8.
(b) Apollo 9: The Duet of Spider and Gumdrop.
(c) Apollo 14: Mission to Fra Mauro.
(d) Apollo 15: The Mountains of the Moon.

No admission tickets are needed. Members may introduce guests.

NOTES ON PRESENTATION OF PAPERS AT SOCIETY'S MAIN MEETINGS

(1) Authors are invited to submit details of any papers which they would like to present at forthcoming Main Meetings, either in the UK or at the European Space Symposia which are normally held abroad.

(2) 20 min. is normally allowed for presentation time at meetings, plus further time for discussion. Papers are usually published in the Society's Journal.

(3) Authors who are precluded by reason of distance or other matters from attending personally, may also contribute a written MSS, to be published as part of the Proceedings of the Meeting.

(4) Short papers may be presented (up to 10 min. duration) on aspects of particular interest which do not lend themselves to presentation as Main Papers, e.g., Research Reports, Current News, or other Statements of Interest. Notice of presentation must be given in good time to allow for incorporation in the final programme.

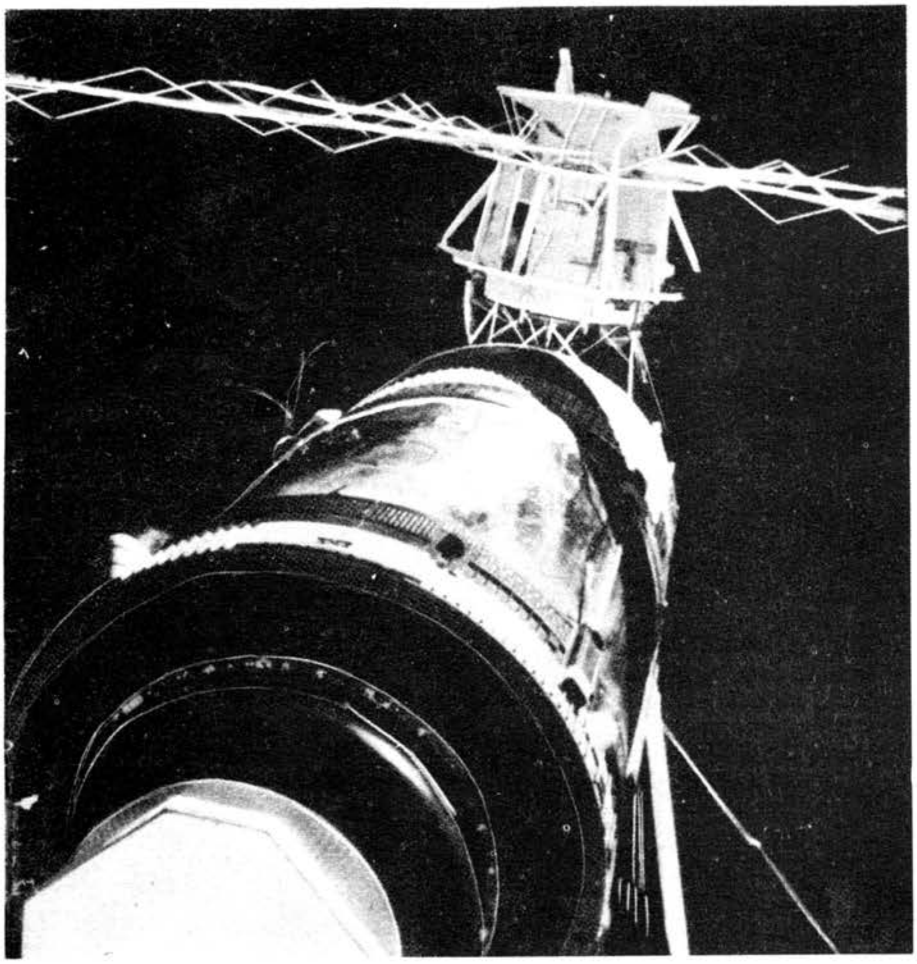
(5) While every effort is made to include the advertised papers in the final programme, the Society cannot be held responsible for any changes which may become necessary for reasons outside its control.

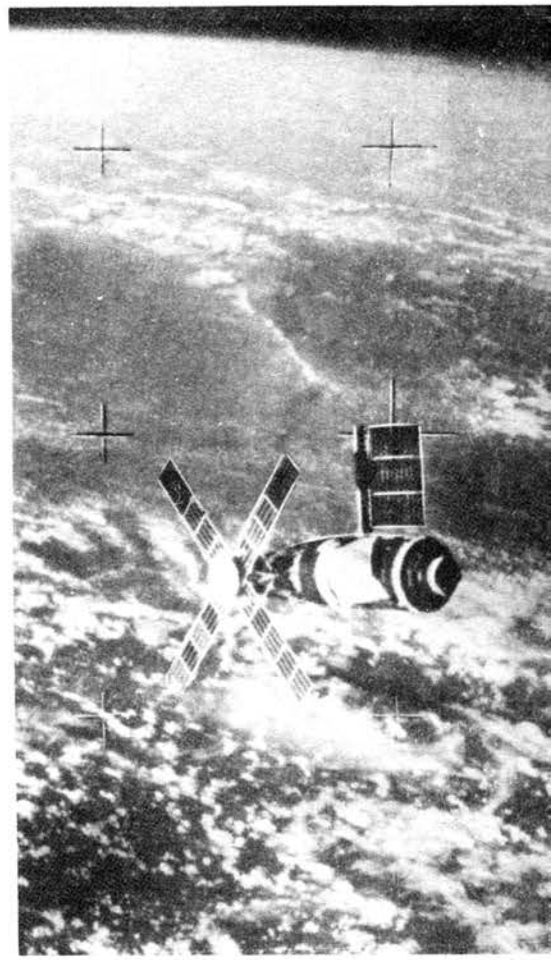
Printed by Unwin Brothers Ltd., at the Gresham Press, Old Woking, and Published by the British Interplanetary Society, 12, Bessborough Gardens, London, SW1V 2JJ.

SPACEFLIGHT

88905 КОСМИЧЕСКИЕ ПОЛЕТЫ № Т-9
(спейсфлайт)
По подписке 1973 г.

Volume 15 No. 9 September 1973





Published by The British Interplanetary Socie

SPACEFLIGHT

A Publication of The British Interplanetary Society

VOLUME 15 NO 9 SEPTEMBER 1973 *Published 15 Aug. 1973*

CONTENTS

COVER

SKYLAB REPAIR MISSION. Close-up of the crippled Skylab space station in orbit 430 km above the Earth, *top left.* In the foreground the micrometeoroid shield is missing, also at left the solar wing. At lower right the companion wing is partly deployed. Above is the Apollo Telescope Mount (ATM). Astronauts Pete Conrad, Paul Weitz and Dr. Joseph Kerwin inspected the damage before entering the workshop. They later deployed a 'parasol' from inside to cover the exposed area and cool down the craft. The stuck wing was manually deployed during a space walk. *Right,* how Skylab appeared after the repair operation with parasol open and the remaining solar wing fully deployed. *Below,* Pete Conrad (followed by Weitz and Kerwin) being welcomed aboard the aircraft carrier *USS Ticonderoga* after spending a record 28 days in space. Story begins on page 334.

United States Information Service

MILESTONES

June

18 Skylab astronauts Conrad, Weitz and Kerwin break world duration record for a single space mission set by Soyuz 11/Salyut 1 cosmonauts at 17 days 18 hours 21 minutes.

19 Conrad and Weitz spacewalk from Skylab for 96 minutes beginning just after 1100 GMT to replace ATM film canisters and repair one of 18 storage batteries (by tapping a regulator with a small hammer) restoring 200W of power.

22 Apollo CSM separates from Skylab at 0858 GMT. Astronauts splash down in Pacific at 1350 GMT about 1.335 km south-west of San Diego, California, after record space mission lasting 28 days; transfer directly to recovery carrier *USS Ticonderoga* within command module by crane pick-up from ship.

27 Mr. Michael Heseltine, UK Minister of Aerospace and Shipping, at SBAC Dinner, says he 'can see no logical objection to having an integrated European space programme, including L3S (the new French rocket project), in which individual projects are paid for according to the interests of Member States – and that may be a nil interest. We would not expect everyone to have the same interest in maritime satellites as we have, and accordingly we would be willing (as the French are on L3S, and the Germans on Space Lab) to pay a corrrespondingly larger share of the cost of such a project'.

30 Concorde 001 during solar eclipse flies supersonically across North Africa in Moon's shadow at 17,000 metres (56,000 ft) for 2 hours 6 minutes from Chinguetti, Mauritania, to a point north of Fort Lamy. Seven scientists on-board observed total eclipse conditions for 74 minutes (maximum observing time on the ground was 7 minutes 4 seconds).

July

2 NASA re-schedules launch of second Skylab crew by Saturn IB from Launch Complex 39B at Kennedy Space Center to 0708 EDT on 28 July. Astronauts are Alan L. Bean, 39, commander; Dr. Owen K. Garriott, 41, science pilot, and Jack R. Lousma, 35 pilot. Splashdown after 56 days scheduled 0838 EDT 22 September.

8 Soviet delegation concerned in Apollo-Soyuz Test Project (ASTP) begins two-week visit to Johnson Space Center, Texas, to gain experience with space equipment and training procedures. Party includes Soviet ASTP technical director Konstantin Bushuyev, cosmonauts Vladimir Shatalov, Alexei Yeliseyev, Alexei Leonov, Valeri Kubasov, Nikolai Rukavishnikov, Anatoli Filipchenko, Vladimir Dzhanibekov, Boris Andreyev, Yuri Romanenko, and Alexander Ivanchenko, and Soviet engineers. (An exchange visit by U.S. ASTP principals, including Tom Stafford, Donald 'Deke' Slayton and Vance Brand, to Soviet training centre at Zvezdnoy Gorodok (Star Town), is scheduled this autumn).

European Space Conference in Brussels breaks up after three hours having failed to agree future programmes, including creation of European Space Agency. Sticking point is divided interests of UK (maritime satellite), West Germany (Space Lab) and France (L.3S launcher). Italy, Sweden and the Netherlands require more time. France expresses disappointment that UK will not join West Germany in supporting L.3S project. Ministers to reconvene in Brussels on 31 July to meet NASA Space Lab decision deadline of 10 August.

PROJECT VIKING

A Special Report on America's Plans to Explore the Surface of Mars, prepared by the Staff of NASA

With the Soviet Union attempting new explorations of Mars, we take this opportunity to present a progress report on America's ambitious project to probe for evidence of life on the Red Planet in 1976. This special feature by the staff of NASA follows a preliminary report on Project Viking by Dave Dooling which appeared in *Spaceflight* in May 1972, pp. 162-166. Details of proposed landing sites on Mars will be found on pages 370-371 of the present issue.

Introduction

The National Aeronautics and Space Administration will launch two spacecraft to Mars in 1975 to soft-land on the surface and test for signs of life. Called Viking, the spacecraft will travel some 700 million km (440 million miles) through space on nearly a year's journey, arriving when the planet is about 330 million km (206 million miles) from Earth on the other side of the Sun. Each 3,400-kg (7,500 lb.) spacecraft will be launched from Cape Kennedy by a Titan III/Centaur rocket during a 30-day launch period between mid-August and mid-September 1975.

After confirming the site data from orbit, each of the spacecraft will separate into two parts, an orbiter and a lander. Together they will conduct scientific studies of the Martian atmosphere and surface. While the orbiter performs TV, thermal, and water-vapour mapping, the lander will conduct analyses of the Martian soil and atmosphere.

The lander's science instruments will collect data for transmission to Earth, direct or via the orbiter, including panoramic, stereo colour pictures of its immediate surroundings; molecular organic and inorganic analyses of the soil; and atmospheric, meteorological, magnetic, and seismic characteristics. It will also make measurements of the atmosphere as it descends to the surface.

The entire lander system will be heat-sterilized before launch to assure that Mars will not be contaminated by Earth micro-organisms. Sterilization will assure that the chances of contaminating Mars are less than one in a million.

Importance of Viking

Is Earth truly a unique life-supporting planet in the immense totality of creation? There is growing evidence to the contrary. Our Galaxy contains 100,000 million stars, many of which are surrounded by families of planets, according to the best astronomical evidence. In studying these stars with telescopes, man has been able to verify that the basic chemicals of which Earth is composed are found throughout the Universe. In just the last century, it has been proven that the ratio of these elements in our own Solar System is consistent with the overall ratio generally observed throughout the Universe.

More recently, radio astronomers have detected simple and more complex organic compounds in interstellar space which has increased our confidence that life could evolve on other worlds. But science cannot calculate the probability of encountering extraterrestrial life in this Solar System and in other solar systems on the basis of this evidence. We cannot tell conclusively by laboratory studies or theoretical reasoning whether the evolution of life is vanishingly improbable or quite likely. We can only estimate the probability by looking around us for signs of extraterrestrial life. The nearest reasonable planet on which to look is Mars.

Mars is dry, cold and less favourable than the Earth for the support of life, but it is not implacably hostile. Life could exist in the harsh climate of Mars, and if it does, we will know that on planets with comfortable climates, similar to that on Earth, the chances of finding life are substantial. We will have strong reason to believe that many inhabited solar systems – perhaps thousands of millions – lie around us in the Galaxy.

Viking exploration may also settle a question of equal importance for determining the probability of life arising out of nonliving chemicals: Is it possible that Mars is lifeless today, but was once the site of a rich variety of life that disappeared later in the planet's history.

The question turns on the abundance of water. Mars is relatively dry today, but discoveries by Mariner 9 of volcanism and riverbeds on Mars suggest that the planet could have had a substantial supply of water that at times became available in liquid form. The water could have remained long enough to permit some form of organism to evolve, only to be snuffed out later when the vital gases and water on Mars disappeared. If that happened, we may still find traces of one-time life on the surface.

Even if no signs of life, extant or extinct, are found on Mars, it is crucially important to study the nature of other planets presumed to have originated at about the same time and by the same processes as Earth. In this context, finding that Mars is without life could be nearly as important as the discovery of life forms. The study of a planet, not too dissimilar from our own, which has evolved in the absence of life would provide us with a yardstick with which to determine, for example, how the atmosphere of Earth has been influenced by the advent of biological processes. Comparative planetology will be of great value in understanding our own Earth, and in formulating measures to protect our own environment.

These possibilities make the exploration of Mars the most important objective of planetary exploration for many decades to come.

Previous Mars Missions

The Mariner Mars flights have supplied most of the Martian data which permit us to plan and design the Viking mission. These data include atmosphere composition, atmospheric structure, surface elevations, atmosphere and surface temperatures, topography, figure of the planet, and ephemeris information.

As a result of the Mariner missions, much experience has been gained also in conducting an orbital mission, inserting a spacecraft into planetary orbit, and processing large quantities of digital data. The design of the Viking orbiter is based on the Mariner spacecraft, with many of the subsystems being nearly identical.

The Mariner flights have provided the logical steps in the exploration of Mars which had to precede Viking, just as Viking is a necessary prelude to eventual sample return by automated roving vehicles and possible manned missions to Mars.

Viking Launch

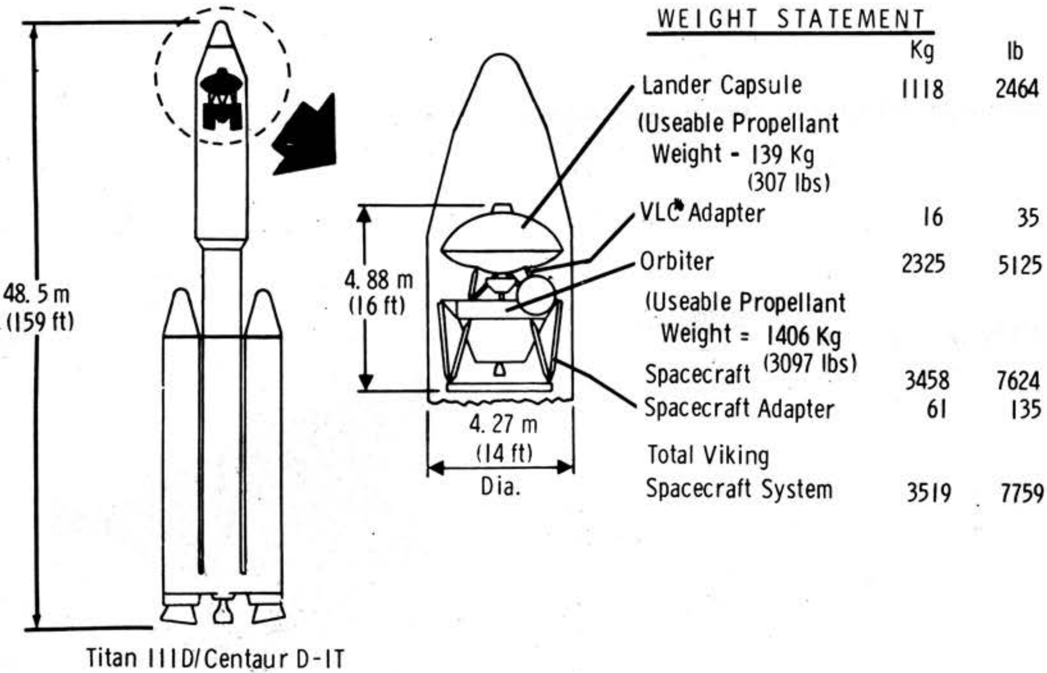
The launch period was selected to provide a minimum energy trajectory from Earth to Mars. Opportunities for such flights occur at approximately 25-month intervals.

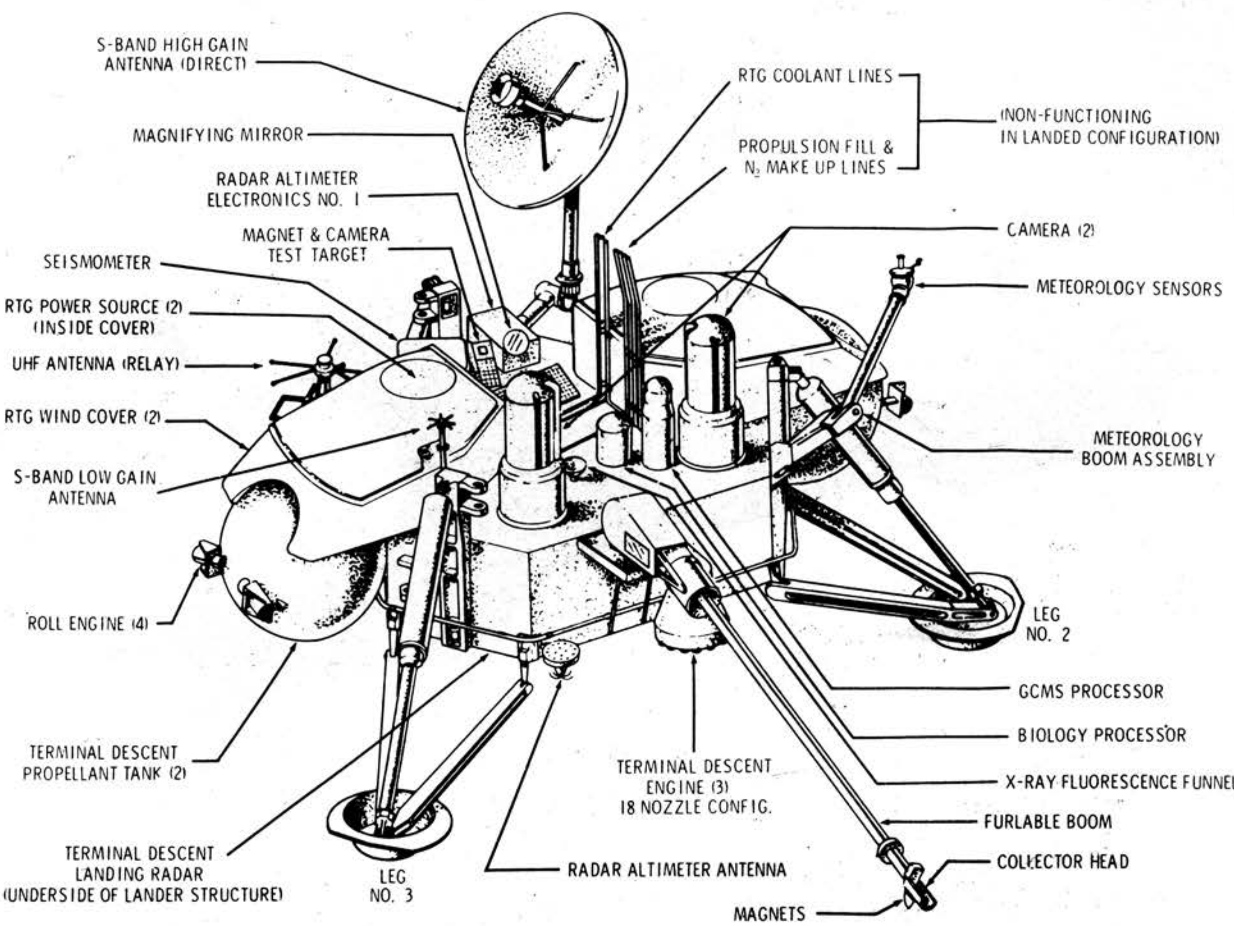
In separate launches spaced at least 10 days apart, two Titan/Centaur rockets will lift off from the Kennedy Space Center, each placing the Centaur upper stage and the Viking

Right, **Viking spacecraft allocated weights.**

Below, Viking landed configuration.

National Aeronautics and Space Administration.



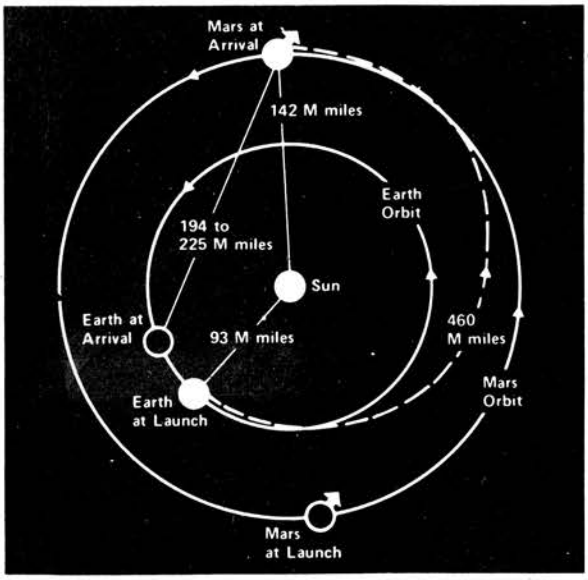


spacecraft into a 184-km (115-mile) parking orbit. After coasting for 30 minutes, the Centaur will re-ignite to send the spacecraft on its journey to Mars.

The Titan booster is a two-stage liquid-fuelled rocket, with two additional large, solid-propellent rockets attached. It is a member of the Titan family used on NASA's manned Gemini programme. The Centaur is a liquid oxygen-liquid hydrogen, high-energy upper stage used on unmanned Surveyor flights to the Moon and on Mariner flights to Mars.

At liftoff, the solid rockets provide 9.61 million newtons (2.16 million lb.) of thrust. When the solids burn out, the first stage of the Titan booster ignites, followed by the second-stage ignition as the first stage shuts down. Centaur ignites on second stage shutdown to inject the spacecraft into orbit. Then after a 30-minute coast around the Earth into position for restart, the Centaur re-ignites to propel Viking on its Mars trajectory. Once this manoeuvre is completed the spacecraft separates from the Centaur which subsequently is deflected away from the flight path to prevent its impact on the surface of Mars.

Shortly after separating from the Centaur, the orbiter portion of the combined orbiter-lander spacecraft orients and stabilizes the spacecraft by using the Sun and a very bright star in the southern sky, Canopus, for celestial reference.



Viking Flight Profile.

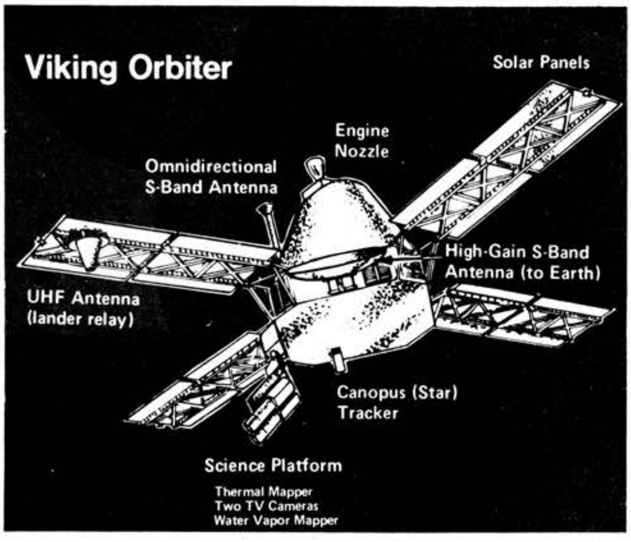
Martin Marietta

Journey Through Space

Viking may have to make several flight corrections during its journey. These corrections will be based on navigation information acquired from Earth-based tracking of the spacecraft. Thus, by firing its orbit-insertion engine several times in a predetermined direction, the spacecraft's trajectory will be altered to insure interception of Mars.

Power is produced by solar panels which open up after injection into orbit, spanning more than 10 metres (33 ft.) tip to tip. Batteries are used when the panels are shaded from the Sun or when peak power is demanded. In turn, the batteries are charged by the solar panels. Small attitude control jets on the edges of the orbiter's four solar panels keep the spacecraft stabilized and oriented.

The orbiter will furnish electric power to the lander until separation. The lander has a set of rechargeable batteries which will be charged during Mars surface operations by two radioisotope thermoelectric generators (RTG's) being provided by the Atomic Energy Commission (AEC). The RTG's convert heat produced by the nuclear source into electricity, making the landers independent of solar energy.



Information concerning flight performance is transmitted to Earth throughout the flight. An onboard computer controls all spacecraft operations and supplies commands for trajectory corrections in addition to controlling the orbiter's scientific equipment while in orbit. At the same time, ground controllers will be monitoring all phases of the mission via the worldwide tracking facilities.

Tracking

The Deep Space Network (DSN) supporting Viking will consist of two networks, each with three stations having 26-metre (85-ft.) antennae and one network of three stations with 64-metre (210-ft.) antennae. The 64-metre stations will be located in California, Australia, and Spain. The California station is now in operation and the other two will be completed in 1973. During most of Viking's interplanetary flight, the craft will be in contact with one of the stations. During orbital operations at Mars, there will be continuous tracking of the spacecraft by one of the larger DSN stations.

In addition to tracking the precise path of the spacecraft, this system processes three kinds of data: engineering telemetry, science, and commands to the spacecraft to initiate or change programmed operations.

Communication with Viking will take longer and longer as the spacecraft gets farther away from the Earth. When it reaches Mars, a one-way message will take 20 minutes. This means a roundtrip minimum of 40 minutes will pass before a command from Earth can be received by the spacecraft in response to its initial transmission. For this reason, automation is essential. Operations that cannot be interrupted, such as the soft landing, will be performed completely automatically by an onboard preprogrammed computer.

Injection into Mars Orbit and landing

As the spacecraft nears the planet, it is manoeuvred into the proper attitude for being placed in orbit. The engine will be fired for nearly an hour to place the combined orbiter and lander in a highly elliptical orbit of 1,500 km (930 miles) by 33,000 km (20,500 miles), a period of approximately 24 hours to match Mars' period of rotation.

The spacecraft will be tracked for at least 10 days after achieving orbit to obtain detailed information for a precise landing, as well as to check out preselected landing sites. Mission controllers will have as many as 50 days to further study the planet to confirm optimum landing sites.

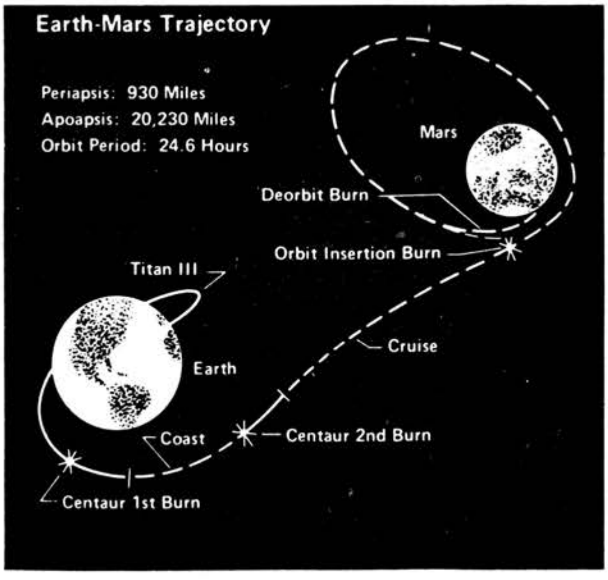
The lander is prepared for separation after confirmation of a landing site based on observational data from Mariner 9 as well as Viking observations. An ideal landing area would be relatively low, warm, wet, safe – and interesting.

Landing

The Viking lander instruments, weighing about 67 kg (147 lb.), are divided into two areas of investigation, those used during the atmospheric entry phase prior to landing and those used on the Martian surface. Entry data will provide information on the composition of the upper atmosphere and on the pressure, temperature, and density of the lower atmosphere.

When a landing area has been determined, the lander's power is turned on, and the lander within its aeroshell separates from the orbiter. The aeroshell shields the lander against the intense heat generated as it decelerates during the high speed entry through the thin CO_2 atmosphere. During descent and landing, the lander maintains communication with the orbiter, which serves as a relay station between Mars and Earth.

A 50-ft. parachute is deployed to further decelerate the lander at about 6,000 metres (20,000 ft.) above the surface. Shortly thereafter, the aeroshell is jettisoned. The parachute is jettisoned about 1.6 km (1 mile) above the surface, and the terminal propulsion system begins firing its three engines.



Viking Mission Sequence.

Martin Marietta

Viking's success on the surface of Mars depends on highly complex equipment, not least the magnetic tape recorder 12 in. long, 8 in. wide and 6 in. high, which can store and play back to Earth 40 million bits of scientific and photographic data per load. Prototype, above, has been undergoing severe environmental testing including vibration, attitude and orientation in 6 different directions, stresses to 7.5 g, and sterilization using 'hot nitrogen' dry heat.

Lockheed Electronics Company

This is a rocket subsystem similar to that used by the Surveyors to soft-land on the Moon. The engines, firing 5 to 10 minutes, slow the lander for a soft landing and shut down just as the footpads touch the surface.

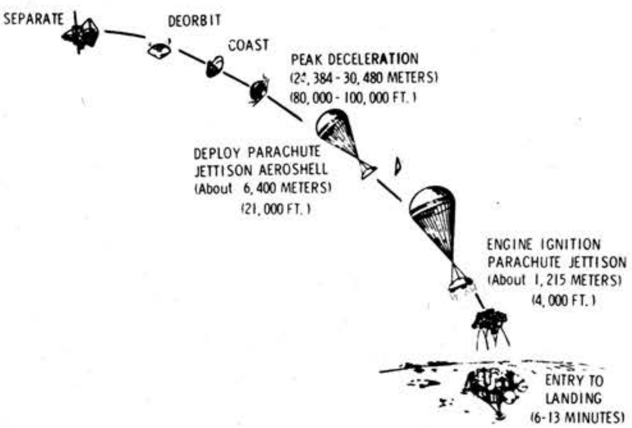
As soon as the lander is on the surface, all systems except those necessary for science operations are shut down to conserve power. The lander's computer immediately determines its attitude on the surface to provide information necessary for aligning the S-band transmitting/receiving antenna with Earth.

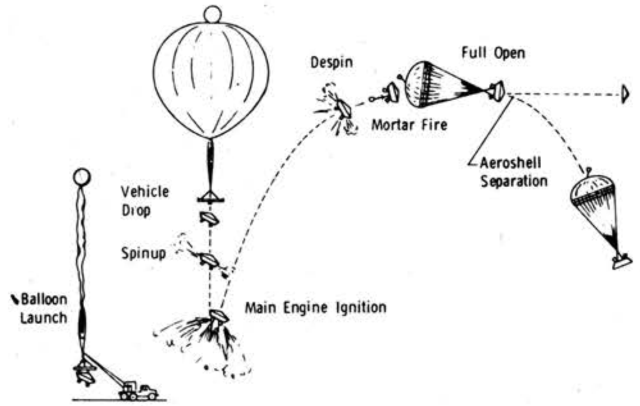
Scientific data and monitoring information are immediately relayed to Earth via the orbiter. At the same time, the two 35-watt (electric) nuclear-fuelled generators are recharging the lander's batteries so operations can be continued for at least 90 days.

The lander instruments consist of a gas chromatograph/mass spectrometer for detecting and identifying organic molecules, the building blocks of life, in the soil; a biology instrument capable of performing three different life detection experiments; three meteorology sensors; a seismometer; an X-ray fluorescence spectrometer for inorganic chemical analysis of surface material; two facsimile cameras; and magnets plus a collector head on a boom to collect soil samples and measure surface properties.

The cameras will give the 66 principal scientists participating in Viking a vastly improved view, in colour and stereo, of the Martian topography and surface structure. Of even greater interest to life-scientists will be the results obtained from the organic and inorganic analyses of the Martian soil, and from the three life-detection experiments.

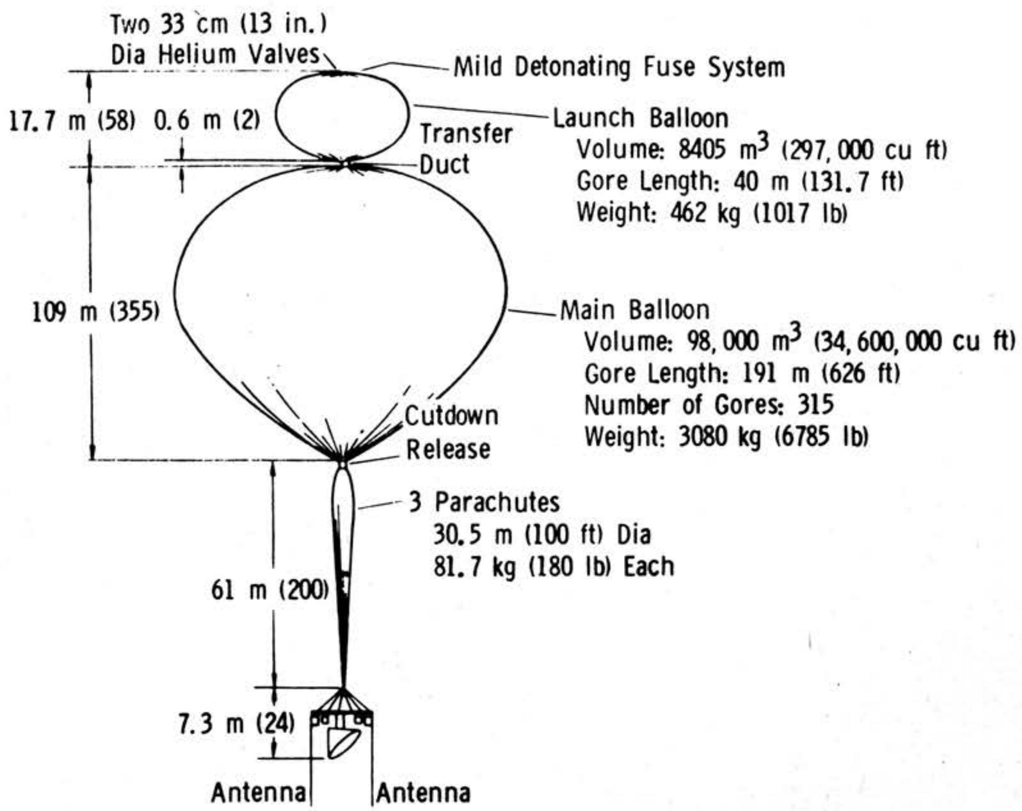
Lander instruments will also determine the temporal variations of atmospheric temperature and pressure, and wind velocity and direction; seismological characteristics of the planet; the atmospheric composition and its variation; and the magnetic and physical nature of the surface.





Above, left, Viking lander descent profile on Mars.

Right, and below, a series of three very high altitude tests of the parachute system that will lower Viking lander to the surface of Mars have been made above New Mexico. In two tests, spacecraft simulating the Mars entry vehicle were carried to about 36.6 km (120,000 ft.) by a large helium-filled balloon, then released and rocketed to high velocity to an altitude of 44.8 km (147,000 ft.). In third test, a smaller balloon carried the test spacecraft to 28.1 km (92,000 ft.). The craft then was allowed to free-fall to the desired subsonic test conditions.



National Aeronautics and Space Administration

Orbiter

While experiments are proceeding on the surface, the Viking orbiters will be circling overhead, observing the landing site, so that local measurements made by the landers may be correlated with overall surface effects. The orbiters will look for conditions such as buildup of dust storms, cloud formation, variations in temperature and humidity, and the passage of the seasonal wave of darkening.

The Viking orbiters each carry about 65 kg (144 lb.) of instruments, consisting of two-high-resolution TV cameras, and infrared spectrometer and an infrared radiometer. These instruments will be employed to survey landing sites both before and after lander deployment in order to provide data on surface temperature, atmospheric water concentration, the presence of clouds, and ust storms and their movement, the topography and colour of the terrain, and other information to describe the broader aspects of the landing site and its relationship to the overall planet characteristics. This information will then be integrated with the lander data for a better understanding of what is happening on the surface.

Viking Investigations

The Search for Life

If life exists on Mars, it is probably in the form of microorganisms. To search for evidence of their existence in the surface samples, three different investigations will be performed. The biology instrument will examine three different soil samples, which will also be analyzed by the molecular analysis instrument for organic content and by the X-ray fluorescence spectrometer for chemical composition.

Photosynthetic Analysis – Photosynthesis is the process by which organic compounds, such as carbohydrates, are formed by combining basic compounds like carbon dioxide, water and salts, using the Sun as a source of energy. It is a basic life-sustaining process; plant life on Earth consumes carbon dioxide during photosynthesis.
In the Viking experiment, a soil sample is inocculated with carbon dioxide gas that has been labeled with a radioactive tracer. The soil and gas are then allowed to incubate in simulated Martian sunlight for a period of time. Later, all remaining gas is flushed out of the chamber and the sample is heated to 600°C (about 1100°F). The heating will liberate any of the labeled carbon dioxide incorporated into organic molecules in a photosynthesis process, and the liberated gas can then be measured. A substantial quantity of labeled gas would indicate that a photosynthetic process had taken place, which would be strong evidence of the presence of living plant-like organisms.

Metabolic Analysis – It is possible that the organisms sustain life by obtaining nourishment from organic materials rather than through photosynthesis. Therefore, an analysis very similar to the photosynthesis reaction analysis has been planned, which will 'feed' organic compounds containing radioactively labeled carbon to the soil sample, sugar for example. If organisms are in the sample, and they can consume the food offered to them, they will discard as waste, radioactive carbon gases that can be measured. A sharp rise in the production of such metabolic gases would be strong evidence that life is present.

Respiration – As metabolism takes place, the composition of the gaseous environment is in a state of continuous change. For this analysis, which is closely related to the metabolic conversion analysis already described, the sample is wet with a growth medium.
A sample of the Martian atmosphere is pumped into the chamber headspace above the sample and monitored. Changes in the composition of the gases will again be evidence of the existence of life as a result of cellular respiration.

In the event of positive results from one or more of these experiments, a control sample will be prepared to further verify the evidence. The control sample is heat-sterilized to ensure that all living organisms are destroyed before analysis is made. Then, if the result is changed, scientists can be relatively certain that the original result was due to the existence of living organisms.

Molecular Analysis

This investigation will perform a chemical analysis of the Martian atmosphere and soil. The chemistry is important in all scientific aspects of understanding the planet, but particularly so for biology. All known life is organic (composed of substances such as sugars, fats, and proteins).

The composition of the atmosphere is important in understanding the overall chemistry of the planet and in attempting to trace the history of its information.

Both the atmospheric and soil analysis consist of detecting and identifying specific molecules by using a device called a gas chromatograph-mass spectrometer. For the atmospheric analysis, the method is simply to 'sniff' the Martian atmosphere with the mass spectrometer. The device is sensitive to one part per 10 million, and will detect any volatile chemical whose molecular weight is less than two hundred. Seasonal variation in atmospheric composition may strongly influence or be evidence of biological activity, as might unusual isotope ratios or compound in unstable equilibrium with the environment.

The soil analysis is more complex. The instrument contains several tiny ovens; each can receive a soil sample from the soil processor. The ovens are heated to 500°C (about 900°F). During heating the organic compounds are vaporized and analyzed. If a living system has not evolved on Mars, the organic analysis may help explain and provide knowledge of pre-biological organic chemical evolution. A high yield of organic material would support a positive active biology result or, in the absence of a positive active biology finding, suggest the possible presence of organisms which did not respond to the conditions in the biology instrument; a high yield of organic material in the absence of a positive result for active biology could be indicative of earlier biological activity.

Inorganic Chemistry

This investigation will perform an elemental analysis of the Martain soil. The elemental composition will identify existing rock types on the planet and is important in determining the degree of differentiation that has occurred on the planet. The inorganic composition and character of the surface are important to the biologists as well as to geochemists and planetologists.

The analysis will be performed by an X-ray fluorescence

spectrometer. The instrument consists of two radioisotope X-ray sources which bombard the surface material, inducing X-ray fluorescence, and four thin-window proportional counters which detect and differentiate the spectrum of the induced fluorescence. The instrument is capable of quantitative analysis for most major, minor, and some trace elements with a sensitivity range of 0.02 percent to 2.0 percent depending upon the element.

The sample to be analyzed would be obtained by the surface sampler and delivered to the instrument by the soil processor and be a part of the same sample examined for organic content and living organisms.

Imaging System

Viking will extend our knowledge of Mars by examining unique sites at a high resolution than previously obtained. The Viking visual imaging system on the orbiter will obtain pictures with a resolution of about 50 metres (165 ft.) per TV line at an orbiter altitude of 1,500 km objects about twice the size of a football stadium.

The orbiter system consists of two identical cameras, each composed of a telescope, filters, TV tube, and appropriate electronics.

Prior to initiation of the landing sequence, the orbiter cameras will aid in confirmation of the preselected landing sites or, if necessary, in the identification of suitable alternatives. After landing, the lander observations will be available to verify and extend the interpretation of orbiter camera pictures for a more detailed understanding of the physical and chemical characteristics of the surface areas other than the landing sites. Valuable data are also expected relative to variable features such as clouds, dust storms, and seasonal albedo changes.

Picture 1 is taken by Camera 1 and stored in the tape recorders. Picture 2 is then taken by Camera 2 and, while it is being put in the tape recorder, Camera 1 is prepared for taking Picture 3 by erasing the previous picture from the TV tube. This process is repeated until the required pictures are acquired.

Lander Camera

On the Viking lander, two facsimile cameras will substitute for man's eyes. They can be directed to look down at the ground nearby, or perform a 360° panoramic scan of the entire landscape.

The cameras will take pictures in high quality black and white and colour, and in the near infrared region of the spectrum. Pictures taken by the two cameras can also be combined to yield stereoscopic views of the areas.

The pictures will convey a great deal of information about the geological character of the surface of Mars, and could identify any higher form of life that may exist. Clouds and dust storms may be seen. The cameras will help in selecting the places where the surface sampler is to dig for soil specimens to be analyzed by the other instruments. Pictures of the digging itself will provide information on the physical properties of the soil.

The facsimile camera operates by using a small mirror which scans a vertical line and projects the image light intensity slowly onto a small detector. After that line is scanned, the camera is turned three degrees and another vertical line is scanned. This process is repeated many times to build up an image from the many scan lines. The detector is a small photocell that converts the light in the picture image to an electronic signal which is then transmitted to Earth. The picture is obtained by reversing the process, converting the electronic signal to a light which is scanned over a film to prepare a negative for making the photograph.

Entry Science

As the lander enters the atmosphere and descends to the Martian surface, there will be an opportunity to learn about the structure and chemical composition of the atmosphere.

Atmospheric chemical composition will be measured at short intervals during the lander aeroshell's descent to identify changes in composition at different altitudes. This investigation will show the proportions of gases such as carbon dioxide, nitrogen, oxygen, argon and of particles such as ions and electrons. Pressure, temperature, and density variations with altitude will be measured during the descent at low altitude, to determine the atmosphere's vertical structure.

These investigations are divided into two phases: The aeroshell phase (entry) and the parachute phase (descent). During the aeroshell phase, atmospheric composition, temperature, pressure, and density will be observed. To accomplish this, temperature and pressure sensors, a magnetic sector mass spectrograph, and a retarding potential analyzer are mounted on the aeroshell. After aeroshell separation, temperature and pre pressure sensors on the lander itself will continue the measurements to the Mars surface and provide supporting data on the surface for the duration of the mission.

The mass spectrometer measures the relative amounts of the gases making up the atmosphere as well as identifying the molecules. The retarding potential analyzer measures both the concentration and the energies of upper atmosphere ions and electrons. Atmospheric density is derived from the pressure composition data together with the aerodynamic drag on the spacecraft as indicated by the accelerometers.

Water Detection

The Mars atmospheric water detector on the Viking orbiter can detect very small amounts of water vapour with a high resolution.

The water detector is an infrared spectrometer which operates on the following principle: If water vapour is in the atmosphere, it will absorb a particular part of the infrared light that is produced by the Sun in much the same manner that ozone in our atmosphere absorbs the ultra-violet light, or a yellow filter absorbs all colours except yellow. The infrared spectrometer can determine that the particular part of the infrared light has been absorbed and how much has been absorbed. This in turn tells the scientists that there is water vapour in the atmosphere and how much.

Thermal Mapping

The intensity of the infrared energy that is radiated by the Mars surface is an indicator of the surface temperature. The infrared thermal mapper on the Viking orbiter can measure the radiated energy and therefore provide scientists with the data necessary to determine the surface temperature on Mars. Similar measurements were made by Mariners 6 and 7 and 9; however, these measurements cover narrow strips of the surface. The Viking thermal mapper will cover large continuous areas at a better resolution than previously obtained. Thermal mapping data will contribute significantly to the selection of landing sites and provide a temperature map of much of the planet at various times, both day and night. In addition,

scientists may be able to locate features such as volcanoes, using the temperature information provided.

Radio Science

The radio communications system can be used as a scientific instrument by measuring the alterations of the radio signals caused by the planet and its atmosphere.

As the radio signal passes through the atmosphere, the signal is changed and observation of the type of change will help define the atmosphere.

The radio system – including the radar – will be used for measuring the gravitational field of Mars, determining the axis of rotation, measuring the surface properties, and performing certain relativity experiments. It will also be used to determine the location of the lander on the ground.

A special radio link, the X-band, is very useful for studying charged particles, the ions and electrons. This is particularly so for measurements of the ionosphere of Mars. It also will be used for solar corona experiments when Mars and the Earth are lined up with the Sun.

The radio data will be received by the three large 64 metre (210 ft.) antennae of the Deep Space Network; the large antenna at Jodrell Bank will also receive signals for an experiment in long-based interferometry.

Weather Station on Mars

Weather has been an important factor in shaping the thermal history and geological character of Mars. The meteorological conditions also affect any life that may exist on the planet. Like Earth's, the dynamic weather conditions on Mars undergo cyclic changes both daily and seasonally.

Periodic measurements will be made of the atmospheric temperature, pressure, and the wind speed and direction for the duration of the mission.

Physical and Seismic Characteristics

Geological measurements will be made of the physical and magnetic properties of the surface and of the internal seismic activity. Scientists do not know the level of motion within Mars, but will record for periods long enough to establish whether it is a very active planet or not. Such information could shed light on the early history of the planet.

A sensitive miniaturized seismometer is mounted on the lander. The seismic background and the larger events, such as Mars-quakes or meteoroid impacts, are measured with a 3-axis device capable of detecting ground motion transmitted through the lander legs. The instrument uses a rapid data mode during special seismic events to obtain much more data during those periods.

The magnetic properties of the planet are measured by small but powerful magnets mounted on the lander soil sampler. These magnets will come into contact with the surface during soil sample acquisition, then will be manoeuvred in sight of the Viking cameras to be viewed with and without a 4-X magnifying mirror. Pictures of clinging particles will be evidence of magnetic material in the soil.

The cameras will also photograph the footprints of the lander and the trough made by the sampler, enabling scientists to study the cohesive properties of the soil, its porosity, hardness and particle size. Such observations will help them to deduce information about the physical properties of the planet's surface. Observations of the trough over several weeks' time will also give an indication of particle transport and the erosion potential of Martian winds.

Communications

Both the orbiter and the lander are capable of communicating with Earth. The lander system is limited by power and thermal constraints to transmission periods of several hours daily. The orbiter system can transmit at high data rates continuously and can also be used as a relay station for data transmitted from the lander. Both the lander and the orbiter have data storage systems which collect data at rates higher than the transmission rates to Earth, and both can be commanded from Earth to send data.

Three kinds of communications systems are involved. S-band microwave links are used to transmit information, receive commands from Earth, and to measure velocity and distance. UHF links are used to relay information from the lander to the orbiter. Finally, as a special technique for science use, there is an X-band link from the orbiter to Earth.

The S-band systems both on the orbiter and lander employ broad and narrow beam antennae. The narrow beam, high-data-rate antennae must be carefully oriented toward Earth. To accomplish this, the antennae are steerable. Due to the planet's rotation, the antenna on the lander must be moved continuously during each transmission period. The fixed broad beam, low-data-rate antennae are used to receive signals from Earth.

The lander-to-orbiter communication link is an ultra-high-frequency (UHF) system that is used for rapid, high-volume transmission. The orbiter records these data and then plays them back to Earth over its S-band system. The X-band system on the orbiter is used for radio science only. The orbiter/lander UHF system begins operating when the lander separates from the orbiter, and continues operating throughout the descent and landing. The relay link will be activated again each day when the orbiter passes over the lander.

Management Responsibilities

Viking management is under the overall direction of the Office of Planetary Programs, Office of Space Science, NASA Headquarters. Langley Research Center, Hampton, Virginia, exercises overall project management and is responsible for the lander portion of Viking. The Jet Propulsion Laboratory, Pasadena, California, is responsible for the orbiter and the Deep Space Network. Lewis Research Center, Cleveland, Ohio, is responsible for the Titan/Centaur launch vehicle and integration of the spacecraft to the launch vehicle. Kennedy Space Center is in charge of launch operations.

Major contractor is the Martin Marietta Corporation, Denver, which is responsible for the lander and systems integration and builds the Titan III booster. General Dynamics/Convair, San Diego, California, builds the upper-stage Centaur.

Progress reports on Soviet missions to Mars will appear in subsequent issues. We are also preparing a major feature on NASA's 'double planet' mission, passing Venus and Mercury, which begins in October. –Ed.

NEXT MONTH

The October issue of *Spaceflight* will include the first of two major articles, 'Children of the Dawn', looking into the feasibility of sending space probes to explore the asteroids and comets. An illustrated feature 'After Apollo' questions the future of astronautics, and we continue our major review of the Skylab missions.

VIKING LANDING SITES

A valley near the mouth of the 20,000 ft. deep Martian 'Grand Canyon' has been chosen by NASA as the site of its first automated landing on the planet Mars. The landing site for the second mission of the 1975-76 Viking spacecraft will probably be an area about 1,000 miles northeast of the first site, where the likelihood of water increases the chances of finding evidence of life.

Both sites are fairly smooth, relatively calm areas in the planet's lowlands.

Selection of the tentative landing areas was the result of a year-long study and evaluation of 22 potential sites by teams of prominent scientists.

The two Viking spacecraft, carrying life-detection instruments, are scheduled to be launched towards Mars in the summer of 1975, the second about a month after the first. The journey will take nearly a year.

Prime target for the first mission is a region known as *Chryse* (19.5°N, 34°W), at the northeast end of the giant 3,000 mile long rift canyon discovered on Mars by the still-orbiting Mariner 9 spacecraft. The rift system runs out into a series of long channels which resemble dried-out river beds.

The landing site chosen for the second mission is *Cydonia*, in the *Mare Acidalium* region (44.3°N. 10°W), at the edge of the southernmost reaches of the north polar hood, a hazy veil which shrouds each polar region during the winter season, and which some scientists believe may carry moisture.

The sites were chosen on the basis of scientific interest and the probability of landing successfully. Such factors as elevation, terrain roughness and scope. Wind velocities and directions are also critical to a successful landing.

Detailed study was made of the maps produced by Mariner 9 scientists, including pictures with resolutions down to 100 meters (328 ft.) These photographs were correlated with data obtained by other Mariner 9 instruments – infrared spectrometer, and radio – which gave information on temperature, pressure, humidity, and general atmospheric and surface characteristics of Mars. Ground-based radar observations were used to predict the elevation, surface roughness and bearing strength of the landing areas.

Sites were chosen on the basis of the following characteristics:

(a) *Low Elevation.* The Martian atmosphere is very thin. The lower elevations, with a higher atmospheric pressure, provide a greater margin of safety for the Viking Lander, which uses a combination of aeroshell, parachutes and braking rockets to slow its descent.

(b) *Possibility of Water.* Since Viking has as one of its principal objectives the search for life, the search for water is very important. Regions of high pressure are the most likely to harbour liquid water.

(c) *Interesting Geological Features.* The Mariner pictures were studied very carefully in an attempt to select sites smooth enough to land safely while at the same time possessing features of high geological interest.

(d) *Favourable Meteorological Conditions.* High winds are known to exist on Mars, as evidenced by the planet-wide dust storm observed by Mariner 9 and Earth-based telescopes. Very high winds are potentially hazardous to spacecraft landing. By studying wind-induced streaking marks seen on Mariner photographs, scientists can identify and avoid high wind regions. The Viking lander is designed to land in winds with velocities up to 150 m.p.h.

(e) *Smoothness and Slope of Terrain.* The 9 in. clearance under the lander body requires a relatively smooth surface, and to assure landing stability the sites should have slopes no greater than 19°. At the same time, the area must be free of extensive smooth-rock surfaces or thick dust layers. Landing on a smooth-rock surface would make sample acquisition difficult or impossible; a site thought to be covered by a deep layer of soft material could mean inadequate surface bearing strength.

Project Viking seeks to advance significantly scientific knowledge of the planet Mars, with emphasis on determining if life once existed or is now present.

After a trip of 460 million miles, the two spacecraft will go into highly elliptical orbits from which they will study the preselected sites in an attempt to certify that they are safe and scientifically attractive. Then each spacecraft will separate into two parts, an orbiter and a lander. Together they will conduct scientific studies of the Martian atmosphere and surface.

Each lander carries a miniature chemical laboratory which will analyze samples of Martian soil for signs of life. A 10 ft. retractable claw will be used to scoop the soil samples for analysis. Other instruments will analyze the atmosphere, measure pressure, temperature, wind velocity, composition of the soil, and quake activity. The data, transmitted to Earth directly or via relay link with the orbiter, will include panoramic, stereo, colour and infrared pictures of the lander's immediate surroundings.

The lander capsule will have been heat-sterilized before launch to comply with international planetary quarantine requirements, and to prevent false signals in the life-detection experiments.

While the Viking lander probes the Martian surface, the orbiter, will perform visual (TV), thermal, and water vapour mapping.

The *Chryse* (rhymes with 'icy') site is scientifically interesting because it appears to be at the lower end of a long valley where the largest group of 'stream' channels on Mars starts to diverge. The site may have been a drainage basin for a large portion of equatorial Mars, and hence would be expected to have collected deposits of a variety of surface materials. It is also one of the lowest regions studied, about 5 km (16,000 ft.) lower than the mean surface of the planet.

Cydonia, the prime site for the second mission, is even lower than *Chryse* – 18,000 ft. below the mean surface. *Cydonia* (Sy-don'-i-a) was selected because of the possibility of finding biologically-available water.

To look for life is to search for the water. Mars is known to have water vapour in its atmosphere, and the subsurface polar caps are believed to be made up in part of water ice. But scientists are searching for a region that would permit, for short periods, the existence of liquid water. This means landing in a region where the pressure on the surface is at least 6.1 millibars, the minimum pressure required for liquid water to exist, and where the temperature rises at least to 273°K (0°C).

At *Cydonia*, the atmospheric pressure is 7.8 millibars and

temperature may rise as high as 0°C. *Cydonia* is at a latitude that is far enough north to believe that seasonal ice is deposited, and southerly enough to predict that in the summer the temperature rises to the melting point.

In addition to satisfying the selection criteria, the sites offer a unique advantage due to their relative positions; both landers will be within communication and viewing range of both orbiters. Thus one orbiter can be released from synchronous orbit over its lander for low-altitude observations of other regions of interest, while the second orbiter acts as a monitor and data relay station for both landers.

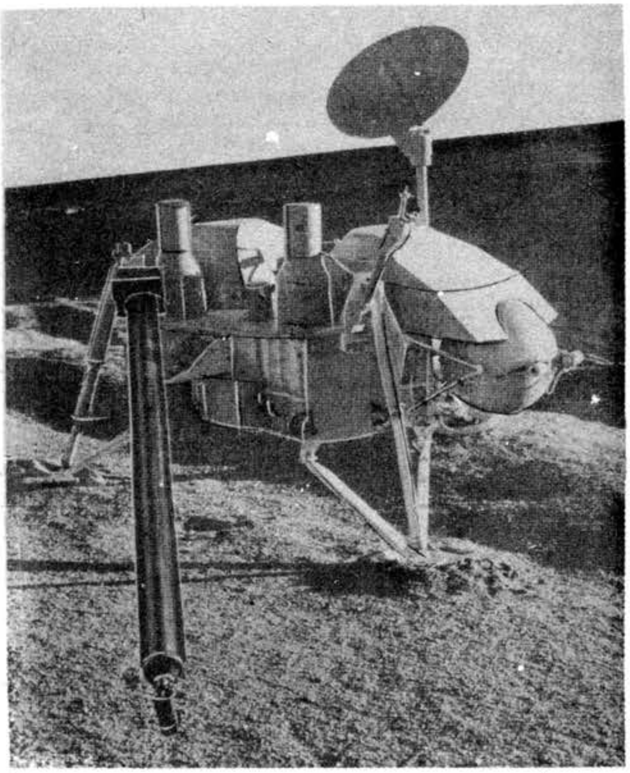
Although mission operations are being planned on the basis of selected sites, if necessary Viking can be retargeted to alternative sites up to the last midcourse correction (about 10 days before encounter). In addition, the spacecraft itself has a limited capability to retarget the lander if observations from orbit prior to lander separation show the preselected site to be unsafe or undesirable.

The backup site for *Chryse* is *Tritonis Lacus* (Tree-tone'is Lah'cus) at 20.5° North latitude, 252°West longitude. If site certification by the Viking Orbiter indicates that *Chryse* is unsuitable for any reason, the lander will be retargeted to *Tritonis Lacus.*

Alba, 'The White Region', is the backup site for *Cydonia.* It lies at 44.2°North latitude and 110°West longitude.

Both the prime and backup sites for the second mission are in the area of maximum biological interest, 40° to 50° north latitude. Current plans call for landings along the 44° line, but the project has the flexibility to switch to 50° if observations from the first Viking orbiter indicate that there is a safe landing site at that latitude for the second mission.

Viking is managed for NASA's Office of Planetary Programmes by the Langley Research Center, which also has responsibility for two of the 6 major systems constituting the project: the Lander System and the Launch and Flight Operations System. Martin Marietta Aerospace, Denver, Colorado, is the prime contractor, responsible for the lander and for project integration. The Jet Propulsion Laboratory manages the Orbiter System, the Viking Mission Control and Computer Center, and the Deep Space Network; and the Lewis Research Center manages the Launch Vehicle System.



Viking: Engineering mockup of lander on simulated surface of Mars.

Martin Marietta

DERIVATION OF MARTIAN NAMES

The *Nomenclature for Mars,* adopted by the International Astronomical Union in 1958, designates the main features on Mars by names drawn from the Bible and mythology, in accordance with the classical system adopted in 1877 by Giovanni Schiaparelli, best remembered for his observations of Martian 'canals'.

Well-known in his own day for his researches on the Bible and the classics, he was steeped in the traditions of Greeks and Hebrews alike. So it seemed natural to Schiaparelli to draw on his familiarity with the ancient work of Earth, and to transfer its geography to new scenes of the world of Mars.

The bright areas of the planet, called 'lands' and 'continents', were named after terrestrial countries, either real, such as *Arabia, Hellas* (Greece) and *Syria;* or mythical, such as *Elysium* and *Amazonis.*

The dark areas were designated seas; for example, *Boreum Mare* (North Sea) and *Tyrrhenum Mare* (Tyrrhenian Sea). Schiaparelli followed his predecessors, in identifying a number of bays, such as *Sabaeus Sinus (*Sabian Bay), and *Aurorae Sinus* (Aurora Bay); some large bays he called gulfs, as for example, *Golfo Sabeo.* Several small dark areas were designated lakes; thus, *Solis Lacus* (Lake of the Sun) and *Niliacus Lacus* (Egyptian Lake).

In fact, a map of Mars looks very much like a map of the ancient Mediterranean world – viewed upside down, of course, since Schiaparelli had formed his picture in the astronomer's telescope which inverts the image.

Thus *Hellus* (Greece), *Ausonia* (Italy), and *Libya* (Africa) border a large 'sea', with *Aeria* (the ancient Greek name for Egypt) and *Arabia* below. *Eden* (Moab) and the four rivers of Paradise – *Phison, Gehon, Hiddekel* and *Euphrates* – are all there, as are *Mare Erythraeum* (Red Sea) and *Bosporos Gemnatus* (the Bosphorus).

Far to the north (if viewed with south at the top) is *Thyle* (Thule), and beyond that is *Ulyxis Fretum* (the furthest of lands). At an opposite corner of the Mars map are *Hades* and *Chaos.* And not much more distant are *Uchronia,* which means a place-without-time, and *Utopia,* which is no-where.

Chryse, the tentative landing site for the first Viking Mission, means 'land of gold', and is believed to be derived from the writings of Ptolemy and later pinpointed as modern-day Burma. Appropriately enough, it is bordered on the Martian map by the *Indus* and *Ganges.*

The landing site for the second mission, *Cydonia,* is the name of a town in Crete, which in turn is named for Kydon, son of the fabled king of Crete, Minos. *Mare Acidalium* is named after the waters in which Aphrodite (Venus), accompanied by the Graces, is supposed to have bathed daily.

MAJOR U.K. ROCKETRY ENDS WITH EUROPA II

A major part of Britain's rocket industry will be destroyed now that the Europa II space rocket has been abandoned. The decision to axe the project was taken by an ELDO Council Meeting on 27 April after Ministers of France and West Germany decided to stop all further contributions to the programme as from 1 May 1973.

The cancellation affects not only the prime contractors for the Blue Streak first stage – Hawker Siddeley Dynamics and Rolls-Royce – but a large number of ancilliary manufacturers of rocket equipment and the Spadeadam static test facility at Spadeadam in Cumberland.

We asked Mr. A. V. Cleaver, Divisional Director and Manager (Rockets) of Rolls-Royce (1971) Ltd., to comment on the background to the cancellation and its impact on the industry which he and others had striven so energetically to build over the past 15 years. Although detailed instructions from ELDO were still awaited, the essential consequences were already clear. Within the next few months, Mr. Cleaver said, all of our Rolls-Royce rocket activities will cease, including the operation of Spadeadam. About 330 of our employees will by then either have become redundant or redeployed.

'This also means the end of any significant rocketry in the UK, apart from work on small tactical guided missiles, and a very limited activity on electric propulsion and attitude control systems for satellites. There will be no continuing work on liquid propellent rocket engines (pump-fed, regeneratively-cooled, or of thrust much exceeding about 1,000 lb.); all the British firms which ever produced such engines had already been absorbed in Rolls-Royce, and any relevant research at official establishments ceased quite a time ago.

Apart from the prospect of being fairly busy for some while longer, in clearing up the above situation, I cannot make any predictions about my own future'.

The background to these sad tidings may briefly be summarised as follows:

Blue Streak, with Rolls-Royce RZ2 rocket engines, was initiated as a military LRBM in 1955, with detailed work commencing in 1956; this programme was cancelled in April 1960.

Discussions were then started (by the UK) with a view to forming ELDO; agreement was reached in 1961, to develop the Europa I and II vehicles with Blue Streak as 1st stage, a French 2nd and a German 3rd stage. (Europa II had a small solid 4th stage, also French).

Since 1964, there have been 11 launches; 10 from Woomera (Australia) and 1 from Kourou (South America). Blue Streak has been successful in all of these. In the first 5, only the 1st stage was required to be operative, but these early trials were then followed by two in which the French 2nd stage failed. In the last four trials, the German 3rd stage has never functioned satisfactorily, and therefore no satellite has ever been orbited.

The programme which has now just been terminated would have continued until the launch of F16 in 1975, with the next launch (of F12) being scheduled for October 1973. This will not now take place, although its Blue Streak 1st stage was already en route to Kourou by ship at the time of the cancellation.

In 1968-69, the UK withdrew further financial support from ELDO, and subsequently re-confirmed this policy, after reconsideration in 1970 and again in 1972. It became UK national policy to rely on American launch vehicles, a decision which was also reflected in the 1971 cancellation of the small Black Arrow vehicle which was part of the national space technology research programme (but which, within some three months of being cancelled, successfully, launched its one and only satellite, Prospero).

A. V. Cleaver, O.B.E., whose endeavours to create a major UK rocket industry fell to the divided ambitions of European governments on 27 April 1973. The Rolls-Royce RZ.2 engines for the HSD Blue Streak first stage of Europa I and II, developed under his supervision, achieved a record of 12 successes in 12 flights. But technical excellence was not enough.

Following the British defection, ELDO continued with fairly firmly-agreed Franco-German support until towards the middle of 1972. The Germans also had by then begun to express misgivings, arising both from the further failure of F11 in November 1971, and continued American persuasion that the new space shuttle would soon render obsolete such expendable ballistic vehicles as Europa II – or the larger projected Europa III. (After the preliminary phases, British contractors finally had no part in this latter, more ambitious, vehicle, because in any case there would have been no funding contribution from the UK). Other aspects of the generally confused and fragmented European space programme were also involved, and led to a very difficult and uncertain situation throughout most of 1972. Only the French wanted to continue with launch vehicles: the British, only with satellites: the Germans, only with satellites and post-Apollo collaboration with NASA (if not on the space tug, then on the shuttle's 'sortie-laboratory').All this could obviously be resolved only at the highest political level, and a meeting of Ministers was finally arranged (after many postponments) for 10 December 1972.

This conference – at least allegedly, and 'in principle'! – decided a surprising number of issues: there was to be a new European Space Agency (combining ELDO and ESRO), with a more flexible arrangement of projects; Europa III was to be abandoned in favour of a new French launch vehicle (the L.3S); a general programme of satellites and post-Apollo collaboration was tentatively endorsed – and also the idea that strictly national projects should gradually be phased-out in favour of collaboration.

However, one issue which the European Space Conference did *not* decide (as it had been expected to do) was the future of the remaining Europa II programme. (By then, of course, it was clear that the remaining British activity on launch vehicles would in any case continue only until mid-1975 at best).

This issue of Europa II was referred to senior officials to agree a decision, at a meeting on the following day 21 December). They failed to do this, but a decision was promised by the time of the next ELDO Council Meeting of 2 February 1973. This also did not materialise, but a decision was then firmly promised 'in good time for April 1' (!) Work was to continue, and funding was assured, until the end of March.

Mr. Cleaver writes:'April 1 came and went without any such pronouncement, but meanwhile in mid-March ELDO had extended our contracts until September 30. The French continued to argue in favour of completing the Europa II programme (at least subject to success at last with F12), while the Germans wanted to cancel it.

The general expectation was that the French view was likely to prevail, and we still thought this after their Minister (Charbonnel) had again met his German counterpart (Ehmke) in Bonn on 17 April. However, it was announced that the discussions between officials would continue after Easter, 'to reach a final compromise', on 24 April in Paris.

The April 24 discussions also did not reach agreement and indeed, they seem to have continued until 27 April, when the French appear to have given in (in return for some undefined German concessions on increased support for the L.3S), so that the ELDO Council held later that day had no choice but to order the immediate termination of all the remaining Europa II programme'.

ELDO Staff Communique

Immediately the cancellation of the Europa programme became known, the Staff of ELDO issued the following communique:

The staff of ELDO bitterly regret that the construction of Europa, in which they believed and for which they have worked for a good part of their careers, has been exposed to disparagement and ridicule by the decision to abandon the European launcher programmes.

It is clear that the failure of these programmes is primarily due to the political incapacity of the Member States to define a common purpose and work together in a genuinely co-operative spirit. The next launch had been scheduled for 1 October 1973, and the ELDO staff protest strongly at the political failure of the Member States being presented to public opinion as a technical failure discrediting their professional ability.

The structure imposed by the Member States on the Organisation for the first 10 years of its existence left national authorities with responsibility for the work done in their countries and in so doing deprived ELDO of all real authority. Only after the failure of the F11 launch (November 1971) did the Member States finally give ELDO the authority it needed to set matters right. The decision to stop the programme halts this endeavour prematurely just before the chance to demonstrate its success.

In addition, it should be pointed out that the development of a satellite launcher inevitably comprises a number of failures from which the lessons are learnt for achieving final success. Only at the price of repeated tests – reflecting their determination to succeed – did the United States manage after a series of failures to develop their first satellite launchers (44 failures out of 107 launches between 1957 and 1961). How derisive in comparison seem the 11 launches spread over 10 years by the Member States of ELDO, which have never been concerned to achieve a genuinely integrated and coherent space policy for Europe but only to defend their special national interests and the short term interests of their industries.

Such an attitude will ultimately discredit, in the eyes of the public, future efforts towards the construction of Europe.

This abandonment also deprives Europe of independence in the space field and establishes an unchallengeable monopoly by the major space powers. As far as large European launch vehicles are concerned the situation now created is irreparable.

This disintegration of the European idea occurs precisely at a time when a Europa II success could shortly have been expected for negligible extra cost compared with the 300 million pounds already spent and whose only justification was a flight-proven launcher.

Considering that their objective of European integration in this area has been frustrated and their careers disrupted, they reprove this abdication by the political authorities.

They refuse to be associated with the responsibility for the waste of not completing a programme of such heavy capital investment, very little use of which can be made, even if the L3S European programme is carried out.

They condemn the wastage of skilled manpower built up over 10 years by ELDO at a time when Europe has to take up world challenges in the technical, economic and human spheres.

BAC AND INTELSAT 4A

A wide range of parts and sub-systems for the latest global communications satellite Intelsat 4A are to be built by British Aircraft Corporation, Electronic and Space Systems, under a £1.2 million ($3 million) contract awarded by Hughes Aircraft Company. This order follows BAC's role as major overseas contractor for the successful Intelsat 4 series of satellites, four of which provide a worldwide 24-hr telephone/TV service from their positions over the Atlantic, Pacific and Indian Oceans.

Manufacture will be at BAC's Bristol Spacecraft Assembly facility and under the 2 year contract a variety of satellite hardware will be produced – spinning structure assemblies, spinning and despun section harness, despun structures, anntenae subsystems support structures and solar panels, etc. The new series of three satellites will be assembled and tested at the Hughes Space Facility in El Segundo, California.

The larger and more powerful Intelsat 4A is designed to meet the accelerating growth in global communications, the majority of which are now routed through satellites. It will be the largest commercial communication satellite built so far with an extended communications capacity nearly twice that of the Intelsat 4 now in service. The new satellite will be nearly 7 metres (22 ft.) in overall length and 2.5 metres (8 ft.) in diameter. The launch weight is about 1,470 kg (3,240 lb.). It will incorporate technology new since the advent of Intelsat 4, particularly in the communication electronics which permit 20 channels (compared with Intelsat 4's 12) each 40 Mhz wide, to be operated through the satellite for at least its design lifetime of 7 years. The improved communication system antennae and electronics will be integrated into the basic satellite design which has resulted in a four out of four success record for the Intelsat 4's launched so far. The first two were launched in January and December 1971 over the Atlantic to provide a service between the United States and Europe. The third was launched over the Pacific in January 1972, and the fourth was launched in June 1972 over the Indian Ocean. The fifth satellite of the eight Intelsat 4 series is due on the launch pad shortly.

SKYLAB – THE DIARY OF A RESCUE MISSION

PART 1

By David Baker

The following is the text of a Statement issued to news agencies (PA, AP and Reuters) by the British Interplanetary Society on the morning of 25 May:

'Today's mission by Charles ('Pete') Conrad and his crew to salvage the crippled Skylab space station will be one of the most difficult and potentially dangerous operations yet undertaken by men in space. If they succeed in getting aboard the station and erecting a heat barrier to cool overheated internal compartments, it will be a clear demonstration of the value of man-in-space for the repair and maintenance of highly expensive equipment. The value of Skylab has been put at around £1,000 million which is about the cost of developing the Concorde supersonic transport.

'Skylab is not intended for abstract scientific pursuits. It includes many experiments which are meant to benefit man on Earth, including observation of Earth's natural resources and global air and water pollution. Other researches are meant to explore entirely new paths for medicine and industry.

'We salute the enterprise of the men and women of NASA who have worked day and night to improvise tools, sunshields and other vital equipment which Conrad and his crew will use in this unique and intensely human space drama. We also salute the enormous courage and resolve of the astronaut team and wish them godspeed in their immense and highly important task'.

Introduction

Early in 1967 NASA went to Congress with proposals for an expanding application of Apollo hardware on missions that would orbit crews in converted S-IVB stages, place space stations in lunar orbit and establish the first lunar colony. The plans then laid would realise a first flight in 1968. Five years on from that launch date the sole remaining vestige of these ambitious journeys set sail for space. In an extensive reappraisal of Post-Apollo plans, Skylab had emerged from gestation and gave promise of greater things to come in the Shuttle era.

Through many years of concentrated effort the Skylab Programme had matured to full space station status and gathered 270 scientific and technical investigations under its wings. It would be a mission of unparalleled magnitude incorporating three periods of occupation totalling 140 days. Hardware preparation was paced by a floating launch date and up to 4 April 1973, postponements continually plagued efforts to get the laboratory spaceborne.

Flight Schedule

The original flight schedule established the launch of the orbital workshop at 17:30 GMT on Monday 14 April, followed by the first three-man crew on the 15th orbit of the clustered station.

The commander of SL-2 was a veteran of three space flights, having served as pilot to Gordon Cooper on Gemini 5, command pilot to Dick Gordon on Gemini 11, and commander to Dick Gordon and Alan Bean on Apollo 12. In addition, Charles 'Pete' Conrad had served as a back-up crewmember for Apollo 9, latterly serving as Chief of Skylab Operations for the Astronaut Office.

Science pilot for the 28 day stay aboard Skylab was Joe Kerwin, the second scientist-astronaut to fly in space and, appropriately, a flight surgeon by profession. With a B.A. in philosophy from the College of the Holy Cross, Kerwin graduated with an M.D. from Northwestern University and went on to complete internship at the District of Columbia General Hospital, Washington. When selected as an astronaut in June 1965 he was serving as a staff flight surgeon for Air Wing Four at the Naval Air Station, Cecil Field, Florida. Kerwin was to wait 8 years for his first flight to space.

Paul Weitz, with a B.Sc. and Masters in aeronautical engineering, the third crewmember, was selected as an astronaut in 1966. All 3 astronauts were seconded from the Navy and Weitz had considerable experience as an instructor and control officer, currently holding the rank of Commander.

The vehicle they would ride to space was Apollo Command/Service modules 116, substantially modified and re-configured for the Earth-orbit role. The demands were different from those of a lunar mission inasmuch as temperature extremes were greater and endurance longer. On the longest stays aboard Skylab the Apollo CSM would experience 840 day/night cycles with the temperature plunging and rising through 140°C. Quiescent in all but essential systems for up to 56 days the ferry craft would be required to support all life support functions during the two-stage retrofire and subsequent re-entry, yet communications equipment in the CSM is vital to the crew, for it is with antennae aboard Apollo that contact is maintained with the ground.

The temperature in the CSM coolant loop was restricted to 60° to prevent condensation and the thermal control system operates continually while on orbit, maintaining temperatures above freezing point in the propellent lines and plumbing. Passive thermal protection ensured that the exterior of the CSM radiates as much heat as possible, relieving loads on the coolant loops. Nevertheless, temperatures on the sunlit side of the spacecraft were expected to stabilise around the 39°C region.

Another responsibility of the CSM was concerned with trimming the orbit of the entire cluster by firing the small 100 lb. thrust RCS engines. For orbital trim and back-up deorbit capability an additional 1,000 lb. of propellent had been provided for the RCS engines, stored in a 12-tank module mounted to sector 1 of the service module.

One of the three fuel cells had been deleted and a 50-gallon storage tank added to take the 325 lb. of water produced by reactions of hydrogen and oxygen for the remaining two fuel cells. By dispensing with water dumps the immediate environment was maintained free of frozen particles vented from the CSM. For 14 to 17 days it was arranged that power was supplied by the fuel cells and distributed to the orbital workshop, followed by total shutdown at depletion of the cryogenic reactants.

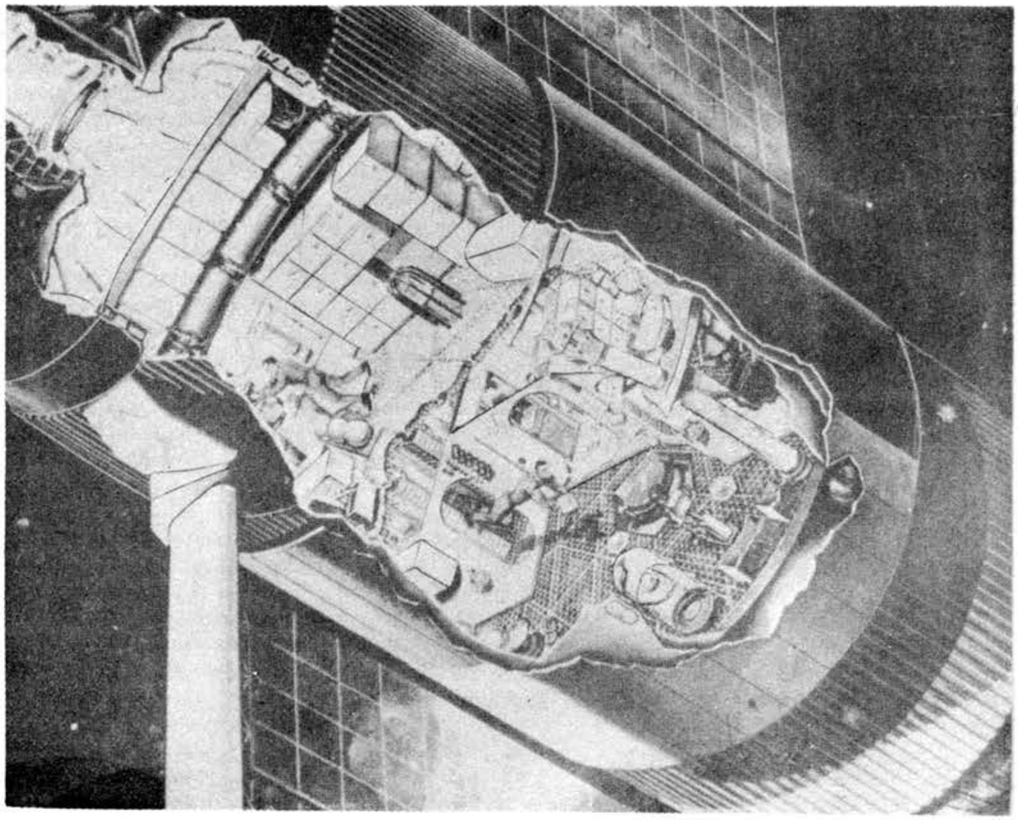
Other changes from the standard J-mission CSM included deletion of 2 SPS propellent tanks and a single helium pressurisation vessel, representing a 50% reduction in SPS ΔV capability, increased locker size and stowage area in the command module, three 500-amp/hr. batteries added to sector 1 of the service module and two 40-amp/hr. pyrotechnic batteries in the service module. The dc power distribution box had been reconfigured and a modified caution and warning system fitted. In addition, an atmosphere interchange duct was added to the upper tunnel and hand rails attached to the lower sections of the couches for ease of access into the CM. Finally, a transfer umbilical assembly was stowed for directing electric power into the workshop.

Launch Configuration

At launch the CSM weighed 30,379 lb, expending 50 lb. of propellent during the rendezvous phase. A notable first on

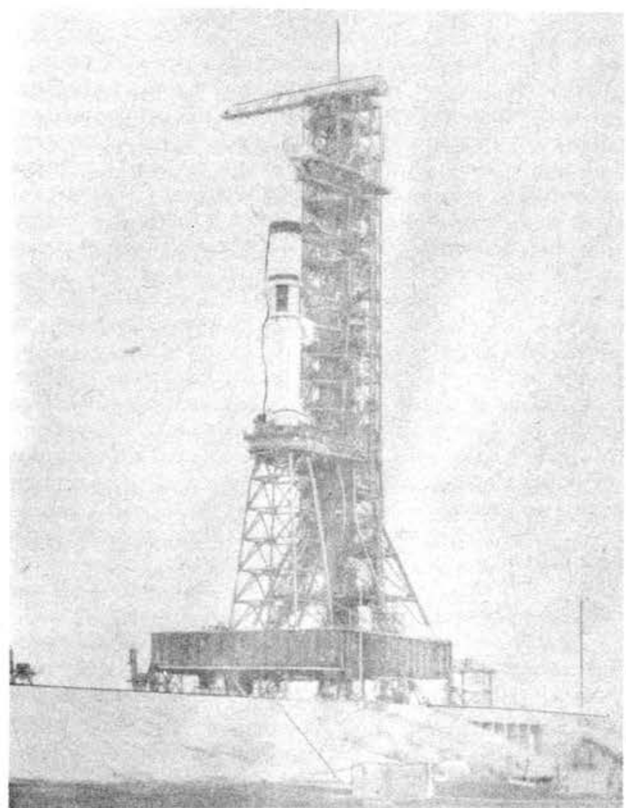
Right, Skylab's spacious interior. Despite loss of power and overheating, the astronauts not only salvaged the space station but quickly got to work on major experiments. With the Apollo Telescope Mount they were able to open new frontiers in the study of the Sun. They also gathered important data on Earth's natural resources, including oil and mineral deposits, and returned information on air and water pollution, flooding, erosion, weather and crop deterioration. The team also used themselves as human 'guinea pigs' in the most extensive medical examinations yet carried out in space.

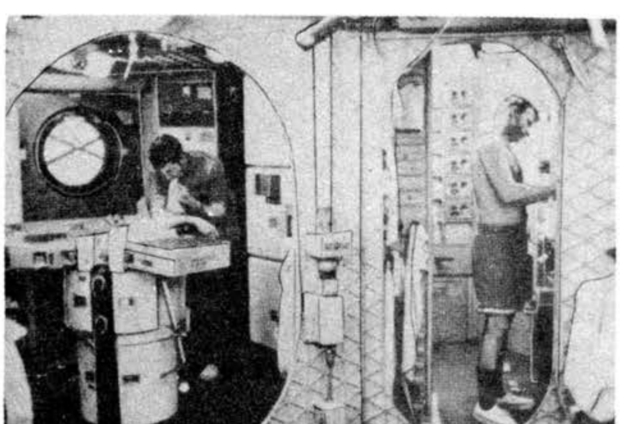
National Aeronautics and Space Administration



Right, Saturn IB launch vehicle that boosted Skylab astronauts Charles Conrad, Jr., Dr. Joseph P. Kirwin and Paul J. Weitz on their way to join the crippled space station on 25 May 1973. Vehicle is mounted on top of a 127 ft. launch pedestal which made the Saturn V mobile launcher systems compatible with the smaller rocket. *Below,* two members of the prime crew of the first Skylab mission are shown during training at Houston – Joseph Kerwin in the wardroom studies the flight plan, and Paul Weitz in the waste management compartment prepares to wash his hands.

National Aeronautics and Space Administration





this flight was the 127 ft. tall pedestal designed to support the Saturn IB/CSM on launch facilities originally conceived and used for Saturn V. By raising the whole stack above the launch platform existing umbilical swing arms could be utilised for the S-IVB, Instrument Unit, and spacecraft. Relocation of the lower swing arms to be compatible with the S-IB was unavoidable. The total cost of the pedestal was $1 million compared with $5 million for completely re-configuring the umbilical arms on the launch tower. In every other way, stacking, roll-out, and servicing duplicated the Saturn V procedures. SL-2, the Saturn IB and CSM combination, stood 223.4 ft. tall and weighed 1,307,095 lb. at launch with a maximum thrust from the 8 engines in the first stage of 1,865,348 lb.

SL-1, comprising the first two stages of the Saturn V, the Orbital Workshop, Airlock Module, Multiple Docking Adapter, Fixed Airlock Shroud, Apollo Telescope Mount and Payload Shroud, stood 344.5 ft. tall and weighed 6,298,829 lb. Several changes were made to SA-513, launch vehicle for SL-1, and these will be discussed in Part 4 of the Saturn V story to be published later.

As launch day approached the pre-flight medical preparations began, pointing up the importance of this first 28 day stay to a basic understanding of the effects of long duration spaceflight on the human body. The countdown on the Skylab cluster proceeded without major problems although the stack was struck by lightning several times, a customary 'handshake' from the elements familiar to launch personnel at the Cape.

Skylab is Launched

The crew for Skylab were at KSC on 14 May to watch the launch of the most valuable single cluster sent to space. Clouds gathered and threatening storms swept into the Cape area. The launch window would last some 3.5 hours but right on time at 17:00 GMT the 5 first stage engines thundered into life, sending shock waves rolling across the marsh and reverberations thundering along the ground to blast and shake the viewing stands 3.5 miles away. The last Saturn V was on its way, 5½ years after the first had lifted off to the cries of a thousand technicians and engineers. With a thrust of 7,750,907 lb. SA-513 accelerated away from the launch tower and disappeared into cloud. Within the first minute the vehicle had accelerated to more than 1,000 ft/sec. and coming up to max-Q, the period of maximum aerodynamic pressure.

At 2 min. 20 sec. the centre engine shut down with the vehicle accelerating close to 4.7g, followed by the outer engines in pairs of two 18 sec. later. Velocity was up to 9,150 ft/sec. at an altitude of 41 nm. Shortly thereafter the second stage engines began a burn that would last more than 7 minutes.

After four min. 40 sec. after lift-off vent valves in the Multiple Docking Adapter closed to preserve the nitrogen atmosphere at 1.3 psia. Later, in orbit, the balance to 5 psia would be provided by oxygen from six 45 in. diameter tanks clustered around the Airlock Module beneath a fixed shroud.

Skylab in Orbit

Two sec. after achieving orbit the S-II stage was pyrotechnically separated and thrusters on the aft end of the workshop swung the cluster around to a nose-down attitude for gravity stabilisation. Fifteen minutes 27 seconds after lift-off the four 56 ft. long sections of the Payload Shroud were severed and ejected at 20 ft/sec. With the cluster thus exposed, the next series of critical manoeuvres would set up the configuration in anticipation of receiving the crew on the following day.

At 16 minutes into the flight, with Skylab coasting 150 miles south of Lands End, the two long discone antennae swung out. These would enhance downlink transmissions later in the flight. Minutes later the electric motors on the Apollo Telescope Mount whirred into life and slowly reeled in the cables, swinging the 24,600 lb. structure to a position 90° from its launch configuration. Throughout this important period an Apollo Range Instrumentation Aircraft (ARIA) had been flying downtrack 100 miles off the coast of Greece to monitor telemetry. The Madrid station had lost signal at the very beginning of this activity.

Twenty-five min. 45 sec. into the flight the solar array system motors were turned on and successful deployment of the four 'wings' was monitored by another ARIA off Mahe in the Seychelles. Less than 2 min. later the operation was complete and Skylab swept on, flying out 236 miles above the Indian Ocean. Thirty min. into the mission the cluster passed into darkness with only 2 major operations remaining.

Shortly before the Carnarvon tracking station acquired the telemetry signals, 52 minutes after lift-off, the timers aboard the Instrument Unit were to have fired pyrotechnic charges to release the two main workshop solar arrays. Covering some 20,336 ft^2 they would supply 60% of the 22.88 kilowatts unconditioned electric power available for station systems and experiments. At acquisition of signal Carnarvon reported that instead of 12.4 kilowatts the arrays were producing 25 watts! Goldstone and Texas, picking up the signal simultaneously less than 40 min. later, were unable to explain the situation which appeared to worsen when additional data indicated a short in the pyrotechnic relay. When Skylab moved again over the Madrid station Houston tried in vain to command deployment of the panels.

The problems were compounded when it was learned that deployment of the meteoroid shield had not and could not take place. The shield, a 0.025 in. thick aluminium sheet, was held close against the outer skin of the workshop during launch for deployment to a 5 in. stand-off position by swing links and torsion bars. This would normally have occurred at 1:35:58 ground elapsed time.

During the first 24 hours NASA management convened to review the situation, cancelling the SL-2 launch and setting up a new schedule. With less than half the design power output Skylab would be seriously compromised if it was required to support the 140 days of manned operations. Little power would be left for experiments. If the manned CSM could be docked to the cluster an additional 1.4 kw could be routed from fuel cells in the service module, but this for only 14 days until depletion of the reactants. Quickly the Houston teams decided on a 20 May launch at 15:00 GMT, for 17 days of near nominal operations followed by a further 11 days of habitation to provide medical analysis of a full 28 days of weightlessness.

Thermal Problems

Within hours another problem had emerged with far more serious implications. The thermal balance of the workshop had been upset when the meteoroid shield, painted white to reflect heat from the Sun, had been torn away. Analysis of photographic records would show that just 63 seconds into the flight the shield had deployed prematurely and ripped apart under the severe atmospheric pressures. Within 24 hours of launch the interior of the workshop was up to 38°C and rising.

Soon plans emerged for a makeshift shade to protect the

exposed areas of the workshop. In concept the design was simple, in practice it was to prove more difficult. Back in Houston, the Conrad team worked long hours trying to develop an abbreviated flight plan and now had their training shifted to a rescue role. The situation looked bleak. May 16 dawned, and 36 hours after launch the temperature had risen to a sweltering 46°C. Before that day was out a gyro malfunction would cast doubts on the integrity of the platform. It seemed to all who were feverishly working to save the crippled Skylab that life was slowly but inexorably slipping away. With power levels at a critical low, temperatures building up by the hour, and guidance problems, the battle began in earnest. Only under the most violent and adverse of circumstances would the station be allowed to die. Hundreds of technicians and engineers marshalled their resources and worked around the clock in desperate attempts to halt the worsening situation.

As 16 May wore on into night, morale was at its lowest and the lights of the Johnson Space Center were added to those of laboratories, factories and institutions across the entire continent. By now the teams were numbered in their thousands. Engineers flew in from vacation as far away as Hawaii and Japan; astronauts stationed themselves at the simulators to be on hand when procedures required a rehearsal. It became a matter of life and death and no one would discuss the catastrophic finality that could come at any hour.

During the daylight hours emergency repair plans had been formulated. The crew could be launched on 20 or 25 May, rendezvous and dock with Skylab, perform an EVA to erect a sunshield, and return to the cluster for a full 28 days in space. The launch opportunities would cycle every fifth day and fall on the 72nd successive orbit due to the repetitious pattern of the ground track. Two flight control teams had been detached from the mission control activities to plan and write-up the contingency schedule. By now several methods had been proposed for lowering the temperatures during the long wait to the manned rescue attempt.

First, the entire cluster was orientated with its broadside to the Sun, accumulating as much sunlight as possible for conversion to electric power. On the next orbit the cluster

Skylab astronauts relax at breakfast before the launch on 25 May. Left to right, Paul J. Weitz, Dr. Joseph P. Kerwin, and Charles Conrad, Jr. Serving the traditional steak and eggs is JSC dietitian Diana Sanford.

National Aeronautics and Space Administration

was turned so that its longitudinal axis, or docking module, was pointing at the Sun and permitting time for the exposed wall of the workshop to cool a little. But there were serious problems with a situation where solar power could be drawn for only 50 minutes in every 3 hours. A compromise was reached whereby the cluster was continually aligned with the longitudinal axis turned 50° away from the Sun, obtaining a useful current for the batteries yet shadowing the critical areas of the hull. From a temperature of 55°C the interior stabilised at a comparatively moderate 39°C.

Sunshades

Several schemes for erecting a shade were proposed in the meantime and tested out in the neutral bouyancy facility at the Marshall Space Flight Center, and in hangars at the Johnson and Kennedy Space Centers. The favoured plan at this time envisaged a two-man crew launch carrying a large thermal curtain in the centre couch position. Earlier plans for a balloon, inflated to 20 ft. diameter from the Airlock Module, were abandoned and replaced with a succession of more feasible concepts.

One of these involved the carriage of 12 four-ft. long rods, screwed end to end to form a 48 ft. pole to be deployed down the side of the workshop. End-tubes would then spring out to form a T, whereupon a crewmember would use a lanyard to haul a thermal curtain back up the workshop to form a square 23 x 20 ft.

By 17 May the Marshall Center had assumed responsibility for evaluating all the many and varied proposals. Three different types of shade were now under consideration and due to the 90 lb. weight-lifting capability of the CSM it was proposed that two be carried, with one as a back-up.

One could be deployed from the Apollo hatch while the other would be attached from the Airlock Module if the prime mode failed. A third design, the so-called 'parasol', arrived for testing and would ultimately gain greater acclaim. This had originated at the Johnson Space Center, the brainchild of Jack Kinzler, Director, Technical Services Division. Hours after the failure he had fashioned a makeshift model from four glass-fibre fishing rods and packed it into a box 8.5 in. square and 53 in. long. For days his team lived and worked at the shops, building a flight-worthy article and adding minor modifications. Deployed from one of the Sun-facing Scientific Airlocks a crewmember would be able to erect this umbrella device without the hazards of an EVA. It was a candidate among many others and would be used by astronauts Schweickart and Kerwin in underwater tests. Meanwhile, at the Johnson Center, other astronauts rehearsed stand-up EVA procedures, station keeping of the CSM, and external sail deployment. By late evening on the 17th JSC received an aft skirt mockup of the converted S-IVB, flown over from the Marshall Center.

Materials for the thermal curtain also arrived from Marshall and the Langley Research Center for testing over the weekend. Working around the clock the engineering teams were headed by J. R. Thompson, Chief of the Man/Systems Branch. He summed up the activities this way: 'There is nothing we're not considering at the moment'.

Many other methods had been probed, among them a spray-on paint and gold-foil matting. Gradually attention centred on the externally deployed curtain but time was pressing for a launch decision. It came before the afternoon hours were set, in a statement from John Discher, Deputy Skylab Programme Director. Conrad, Kerwin and Weitz would be launch-

ed at 13:02 GMT on Friday 25 May. The 20 May launch window was too soon to allow sufficient time for all the many tests to be satisfactorily completed. The crew would rendezvous, conduct a fly-around inspection and dock with the cluster, spending 5 days in the CSM before entering the workshop. A shield, deployed from the Airlock Module, would reduce the temperatures to near normal levels.

Back at the Marshall Space Flight Center engineers conducted tests on simulated film magazines, tapes, medicines and unfrozen food items of the type aboard Skylab. It was feared, that the temperatures which at times reach 70°C, may have seriously degraded many of the more critical items stowed aboard the space station. The results were somewhat pessimistic and a recommendation was made to carry spare film supplies to locker compartments in the workshop. Thermal control of the Airlock Module, Multiple Docking Adapter, and the Apollo Telescope Mount was unaffected and food was the principal item that could deteriorate in the high temperatures. Already the Johnson Space Center had commanded Skylab to vent to a near vacuum to reduce thermal conductivity, marginally easing the situation.

May 18 dawned and with it a new threat to potential occupants of Skylab. The high temperatures were thought to have caused outgassing from the internal wall insulation, creating a noxious additive to the nitrogen/oxygen atmosphere. Dr. Royce Hawkins, Deputy Director of Medical Operation at Johnson warned of the dangers from carbon monoxide and TDI (T-lunidi-isocynate) that could be present aboard the workshop. Concentrations of these gases may be in the region of 2-20 parts per million, more than sufficient to cause permanent lung damage and eventual death. While controllers vented the workshop down in an attempt to expel the gases the crew rehearsed with carbon filter masks and detection devices that they would now have to carry into space. Several times the workshop would be purged before the 25 May launch date dawned.

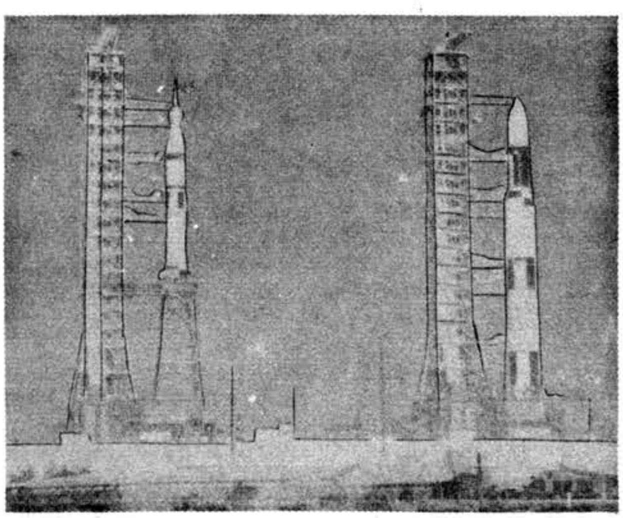
By 19 May the sunshade contenders had been narrowed down. Two types would be flown, with ultimate selection left to the crew. The prime method at this time would require the Apollo spacecraft to be manoeuvred within 10 ft. of the workshop sufficient for a crewmember, standing in an open hatch, to attach the corner of a triangular blanket to the aft skirt. Corrugations in this area would permit an expansion device to satisfactorily moor the corners. Moving up along the hull the forward end would be fixed to a cleat through which a threaded rope would be used to draw the blanket along the exposed wall of the workshop. If this method failed an alternate procedure would be tried, whereby a crewmember would perform an Airlock Module EVA after docking. A 42 ft. long pole could be extended back along the hull from where a 20 ft. square shade would be attached and unfurled to the shape of a fly swat. Moored at the forward end the shade, made from layers of mylar and aluminium, would screen the workshop from the searing rays of the Sun and cool the interior to the required 21°C. The choice had been made and preparations were concentrated on these two designs. Six days remained before the crew would embark on their perilous mission.

Thoughts had been diverted to the possibility of launching a second Skylab to duplicate the flight plan of the first. All the hardware was ready and could be sent aloft within 15 months of the go-ahead. But this would cost a further $325 million, a target beyond the reach of an already strained budget. If Skylab A could not be made to work the entire programme would have to be cancelled. As the hours ticked away these thoughts were a grim watchdog to the new rescue plans and before the crew were launched one final change would be made in the procedures. This time there would be no back-up.

During the daylight hours of 19 May Conrad, Kerwin and Weitz busied themselves in the multiple docking adapter trainer at the Johnson Space Center, rehearsing procedures for deploying the airlock module shroud. In the afternoon they moved to the Apollo command module simulator and turned their attention to the stand-up EVA tasks. Meanwhile astronaut McCandless had been evaluating the various tools that would be carried for attempted deployment of the solar panels, activities rehearsed by Schweickart and Musgrove in the neutral bouyancy water tank the day before.

By 20 May the situation began to change and emphasis swung to the so-called 'parasol'. As fabrication neared completion on all the many shade concepts, and astronauts rehearsed deployment tests in the 40 x 75 ft. water tank at Huntsville, NASA management converged on the optimum design. Basically an off-set umbrella, the parasol consisted of four ribs, each made up from five telescoping booms of 0.359 to 1 in. diameter. The centre pole comprised five interlocking segments for a maximum length of 27 ft. These segments would be added one by one to push the ribs away from the outer surface of the workshop when inserted through the 8 in. opening known as the Scientific Airlock. Two airlocks are mounted in the workshop walls, one on the Sun side and one opposed 180°. Each telescopic rib carries a dual spring assembly coiled from piano wire to permit deployment when the final section was added and the maximum reach obtained. Attached to a common head at the top of the outermost pole the four ribs span out to support a 22 x 24 ft. aluminium/mylar canopy weighing 12 lb. The total weight of the parasol is 95 lb. and compares favourably with other concepts.

During the closing hours of 20 May the decision was made



Deliberate KSC double exposure, at right, shows Skylab and its modified two-stage Saturn V, which lifted off on 14 May, and left, the Apollo CSM on Saturn IB which left with the first boarding party on 25 May. Actually the pads are 1½ miles apart.

National Aeronautics and Space Administration

National Aeronautics and Space Administration



Heroes of Skylab. Left to right, Charles (Pete) Conrad, Jr., Commander (Captain, USN); Paul J. Weitz, Pilot (Commander, USN), and Joseph P. Kerwin, Science Pilot (Commander, MC, USN).

to provisionally adopt the parasol as the preferred method of shading the exposed wall of the workshop, with the A-frame externally deployed shield as a back-up. This latter system would require two crew members to exit the airlock module and attach poles from the Apollo Telescope Mount to the rear of the workshop for supporting an aluminium/mylar shade similar to the parasol. This assembly would weigh 112 lb. Two other alternate concepts were also under evaluation: a sail deployed from the command module alongside the workshop, weighing 30 lb. and an inflatable 'mattress' shield. Both Marshall and Langley Research Centers were developing designs of this latter type. However, training exercises performed on the morning of 22 May caused NASA to abandon the inflatable mattress and concentrate on the other three designs.

Meanwhile, intensive activity was underway to offload unnecessary equipment from the command module, considerably expanding the weight assignment for sail assemblies and providing the possibility of carrying all three candidate designs. Two days before the launch of SL-2 a design certification review on the shields confirmed the order of approach. Conrad and his crew first would attempt to deploy the parasol, followed by the A-frame assembly on an EVA if the umbrella device failed. The second back-up, only adopted if the A-frame method also failed, would be a stand-up EVA from the command module hatch after undocking. The firm favourite, the parasol, was packed aboard a NASA Lear Jet in the afternoon of the same day, 23 May, supported by equipment flown out in a T-38. At 5.20 CDT the Lear Jet rolled down the runway at JSC and headed out on its long trip to the Kennedy Space Center, just as the countdown for SL-2 entered its final phase. Timing was critical and all the resources of NASA were on hand to receive the shades at KSC and rapidly pack the equipment aboard CSM-116 waiting on top of Saturn IB SA-206 for the first planned rescue role in space.

Even in these final hours tension prompted the launch director to move up propellent loading by some three hours. This would provide nearly five hours after fuelling and before crew ingress for installing the three packed sails in Apollo.

Henceforth, all events will be recorded in Central Daylight Time, local time at the Johnson Space Center, as this provides a more meaningful interpretation of specific days in the manned portion of the mission. For purposes of comparison BST is 6 hours later than CDT.

So far we have concentrated on the activities of the 'rescue' teams in their efforts to develop a credible shield against the searing heat of the solar rays. In orbit, some 236 nm above the Earth, Skylab had established a reasonable level of quiescence and for much of the previous week had maintained a holding posture. The massive cluster had been stabilised at a pitch-up angle of 55° by late evening of 17 May, 3½ days after launch, holding most of the temperatures at 40°C. For the next three days the situation remained unchanged and pitch angles varied between 47° and 52°, an optimum level for nominal electric current and minimised heating effects. May 21 brought a flurry of activity in mission control as orientation adjustments created adverse hot spots and food locker temperatures soared to 52.5°C. Tests had shown that 95% of all the stored food would be unaffected by temperatures of up to 54.5°C. Five items however could degrade if exposed to temperatures of more than 46°C, but with a 12% overload on the capacity this 5% loss would be no problem.

By early the next day, 22 May, the internal temperature was projected to be stable at 51°C in the food area. Flight Director Milt Windler held a lengthy conference with the Marshall Center to plan the next few hours. The problem had been compounded by low temperatures in the suit circuit coolant loop of the environmental control system. Pitch the assembly up and the internal temperatures would drop, but the electrical production would also fall off and now the coolant loop could freeze. The lengthy periods spent in an orientation for which the cluster was not designated had begun to take its toll. For most of the day engineers worked to effect a compromise but even as Conrad, Kerwin and Weitz arrived at the Kennedy Space Center, precisely at 7.01 p.m. CDT, events were edging closer to disaster.

Came 23 May and with it the most intensive list of entries in the Skylab event diary. Already the countdown for SL-2 had begun, at 5.30 a.m., and the crew spent 2 hours in intensive medical tests. But still the Skylab in space was only just holding its own. Still the temperature was up around 51°C

and still the coolant loop threatened to freeze. It was a day of decision regarding the orbiting cluster that brought precious hours of reprieve for the flight controllers in Houston. With a food compartment temperature of 53.5°C commands went to the waiting Skylab and at precisely 4:46:40 p.m. CDT the cluster began pitching to reach 65° inclination some 12 minutes later. It was held at this angle for two orbits and then swung down to 45°C for precious electric current to flow into the batteries, moving up to the nominal 50°C five orbits later. It had worked. By 9:00 p.m. the temperature was down to a tolerable 52.5°C.

Also that day leading aerospace contractors met with the directors of the Johnson, Marshall and Kennedy Space Centers, programme directors, mission directors, technical support chiefs and flight control personnel to endorse and fully approve the projected sequence of events for SL-2.

For most of the morning of 24 May Skylab remained pitched up 47° but a repetition of the attitude-juggling activities of the previous evening was necessary to keep the temperatures in the food area within acceptable limitis. During the past few days the internal pressure had been cycled between 0.6 and 2.0 psi in an attempt to vent the noxious gases described earlier. The final cycle went down to 0.1 psi during the afternoon hours and would be up to 0.3 psi at the time the crew were launched.

At precisely 6.58 CDT on the evening of 24 May the NASA T-38 touched down on the skid strip at KSC bearing the Stand-up EVA (SEVA) sail, followed exactly 32 minutes later by the Lear Jet with the parasol. It had been in the air less than 2 hours 10 minutes on its flight from the Houston base. By 11.45 p.m. the Saturn IB was fully fuelled and launch preparation teams moved in to pack the late arrivals aboard the command module, now up to a record weight of 13,364 lb. More than 220 lb. of cryogenic hydrogen and oxygen had been placed in the fuel cell tanks of the service module. Not long before the last strains of daylight had fast escaped west and brilliant searchlights flooded the whole area as a hum of activity swept through the Merritt Island launch area. One of the most exciting chapters in the history of space flight was about to begin.

Several hours before the Mobile Service Structure had suffered a 54 minute delay in its roll-back schedule when thunderstorms gathered and lightening struck the tall structure.

At 1.16 a.m. on 25 May, the subshades were on their way up the elevator to the white-room next to the command module and by 3.20 a.m. the last item was being installed. Just 50 minutes before the crew walked across the access arm to take up their positions in the spacecraft at 5.20 a.m. the centre couch was installed and the race was won. All was now ready for an on-time launch. The remaining events went well and the hours gave way to minutes as 8.00 a.m. approached.

Doubts about an on-time launch had been expressed right up to the previous evening. If a cancellation had been necessary another five days would go by before SL-2 could get off the pad on its M5 rendezvous profile. A 26 May launch would require 20 Earth revolutions for rendezvous, and 19 revolutions on the subsequent three days. Skylab would be seriously imperilled if the crew had another wait.

Mission Day 1:

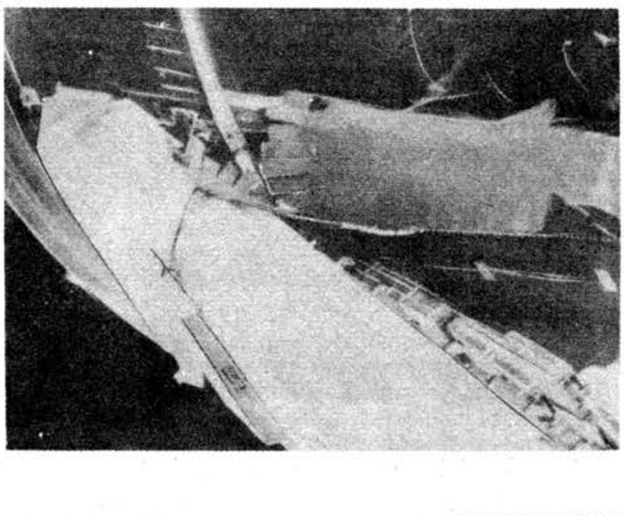
The final moments of the count moved exactly as planned. At T-30 seconds the water deluge began its thunderous cascade and precisely on time the Saturn IB/Apollo sped off on a flight azimuth of 47.58° for a keyhole in space that would, within 7.6 hours, permit rendezvous with the orbiting Skylab. The cluster was 780 nm ahead at launch in an orbit of 234.3 x 239.7 nautical miles. On shift at Mission Control Flight Director Phil Shaffer kept up a status review through capcom Dick Truly. Less than 10 minutes after launch the Apollo CSM was in an orbit of 83.5 x 189.1 nm at a velocity of 25,825 ft/sec. Six minutes later the spacecraft burned a 3 ft/sec separation from the S-IVB stage and preparations began for the long chase to Skylab. The first manoeuvre in the rendezvous sequence, an NC1 phasing burn of 207 ft/sec. came 2 hours 23 minutes after lift-off and raised the orbit to 195 x 201 nm. The CSM was now 600 nm behind Skylab and for 2 hours 18 minutes the manned Apollo slowly narrowed the distance. NC2, the second phasing burn, modified the orbit to 200 x 220 nm despite a 1.6 ft/sec. underburn. The distance to the target ahead was now a mere 250 nm.

Less than 2½ hours after launch the 40 ft/sec. NCC corrective combination burn raised both perigee and apogee to 217 x 225 nm. Thirty minutes later the range was down to 90 nm and shortly thereafter, at a ground elapsed time of 6 hours 5 minutes, a 28 ft/sec. coelliptic combination burn placed CSM-116 in an orbit 10 nm below Skylab. Fifteen minutes later Skylab was only 63 nm ahead and at 7:03 GET the terminal phase initiation manoeuvre started the CSM on its upward curve to a matching orbit with the crippled space station. Exactly 7½ hours after launch a distance of only 36 miles separated the two vehicles and within minutes live TV pictures revealed the true state of the damage inflicted 11 days before. The No. 2 solar array boom was completely missing and the No. 1 boom was partially deployed from the side of the workshop. With the CSM still circling the giant cluster Mission Control gave Pete Conrad a 'go' for soft docking at 8:25 GET before finally losing contact from the stateside tracking stations at 8:14 from lift-off. Some 43 minutes later contact was re-established through the Carnarvon station with the crew eating dinner following a successful soft dock to the multiple docking adapter.

[To be continued.

Below, the partially deployed solar wing trapped by torn aluminium strapping which the Skylab astronauts had to untangle during man's first repair operation in orbit.

National Aeronautics and Space Administration



ANOTHER LEAP FOR MANKIND

The Apollo-Soyuz Test Project Which Could Lay the Groundwork for East-West Co-operation in Space

Introduction

In mid-1975, an American and a Soviet spacecraft are scheduled to rendezvous and dock in orbit 230 km above the Earth. The five crewmen will demonstrate rendezvous techniques, test compatible docking systems for future spacecraft, check out the docking module, and evaluate common operational procedures. And perhaps most important historically and symbolically, astronauts and cosmonauts will exchange visits to the other's craft and conduct joint experiments. The rescue implication of this unique event will be one of the more promising benefits of the ASTP mission.

That mission will be the culmination of the Apollo-Soyuz Test Project. It will mark a commencement that could affect the course of international relations as dramatically and as beneficially as does the lowering of a terrestrial barrier. In the end it could lead to the really dramatic projects which were always the goal of international astronautics – large manned space stations serving Earth and manned interplanetary exploration.

Mission Profile

The following is a tentative mission profile of the flights of the USSR and US spacecraft, according to current planning information:

The USSR Soyuz spacecraft will be launched with a two-man crew on 15 July 1975 at 15.30 hr. Moscow time from the Soviet Cosmodrome at Tyuratam. During the first day, the Soyuz performs manoeuvres to place the spacecraft into the 230 km orbit suitable for the docking operations.

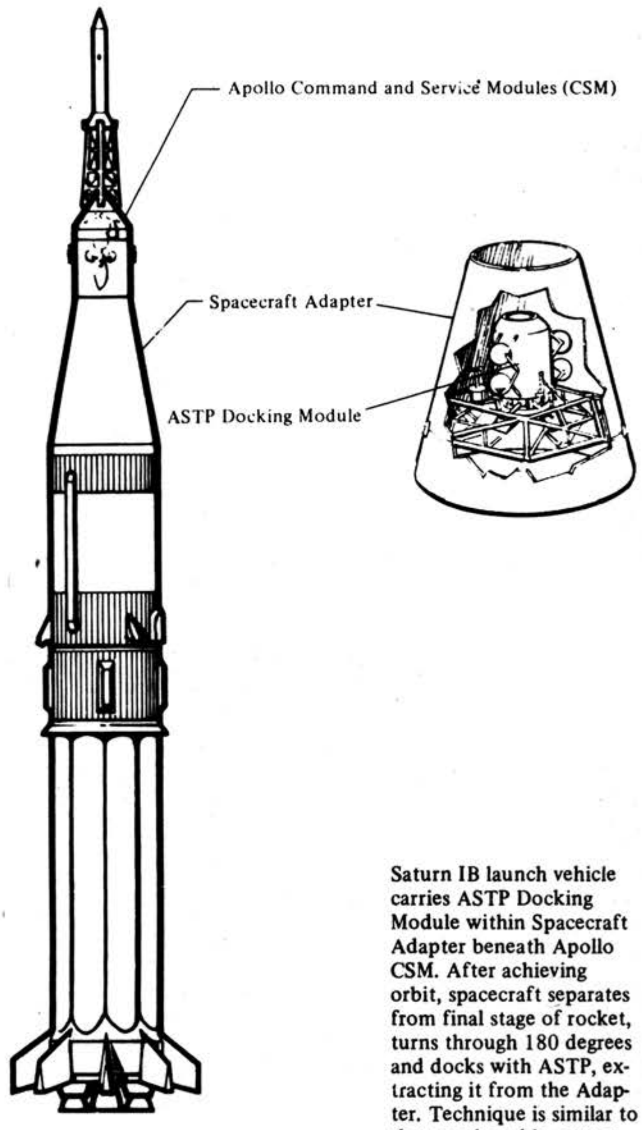
The US Apollo spacecraft will be launched with three astronauts aboard a Saturn IB rocket from the Kennedy Space Center, Florida, approximately 7½ hours after the Soyuz liftoff. After achieving a preliminary near-Earth orbit, the astronauts will place the spacecraft in the proper configuration for docking. The Apollo then will transfer to the same docking orbit as Soyuz.

The docking of the two spacecraft is scheduled to take place about two days into the mission. Once this occurs, the docking module is activated to permit the crew transfers. US astronauts will first visit the Soyuz spacecraft.

During the two days that the spacecraft are linked together each of the crew members in both spacecraft will visit the spacecraft of the other country.

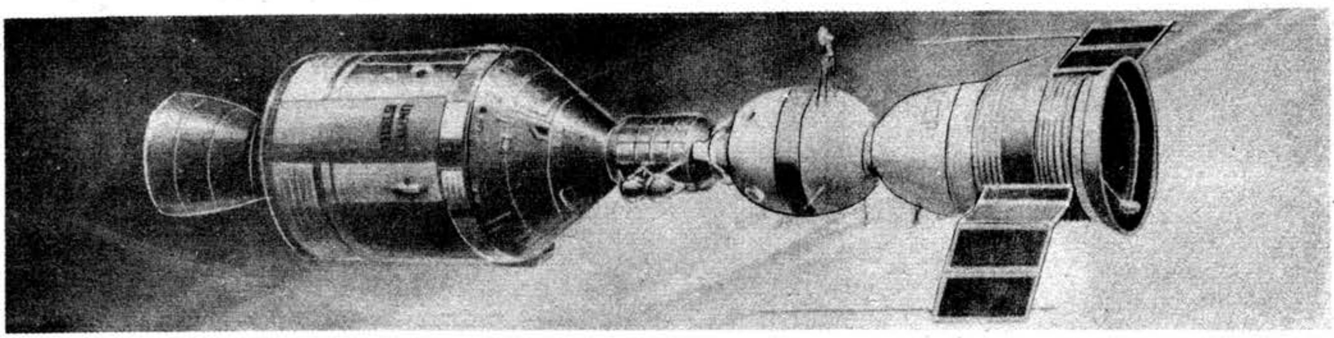
The combined US-USSR crews will perform joint experiments and radio/television reporting from both Apollo and Soyuz.

After the joint docking experiments have been completed, the spacecraft will separate, and both spacecraft will continue on a programme of autonomous flight. The Soyuz will perform a landing in the territory of the USSR and the Apollo



Saturn IB launch vehicle carries ASTP Docking Module within Spacecraft Adapter beneath Apollo CSM. After achieving orbit, spacecraft separates from final stage of rocket, turns through 180 degrees and docks with ASTP, extracting it from the Adapter. Technique is similar to that employed in extracting the Apollo lunar module. *Below,* Apollo and Soyuz in the docked configuration.

Rockwell International



will make a water landing in the Pacific Ocean.

During the whole flight, the ground control centres of both countries will remain in radio communications contact with each other as well as with their spacecraft.

The main goal of the joint flight is to test and evaluate the compatibility of systems for rendezvous, docking and the transfer of cosmonauts and astronauts between future manned spacecraft and stations.

The performance of this test mission will include the following major objectives:

1. Testing of compatable rendezvous systems in orbit.
2. Testing of androgynous docking assemblies on both spacecraft.
3. Verifying the techniques of transfer for cosmonauts and astronauts.
4. The performance of activities and experiments by US and USSR crew in joint flight.
5. Gaining of experience in conducting joint flights by US and USSR spacecraft, including, in the case of necessity, rendering rescue aid in emergency situations.

In addition to accomplishing these major activities, the joint flight plan will also include certain scientific and technical experiments, live TV sent to both nations from on board both spacecraft and joint motion picture/photography activities.

Docking System

For the project the US and the USSR have agreed to use a new compatible docking system that will be developed independently by both countries (see *Spaceflight* November 1972 pp. 402-406). Here is how the systems work during the docking sequence.

After the rendezvous sequence has been completed, the extended docking mechanism of the Apollo will be mated with the retracted docking mechanism of the Soyuz.

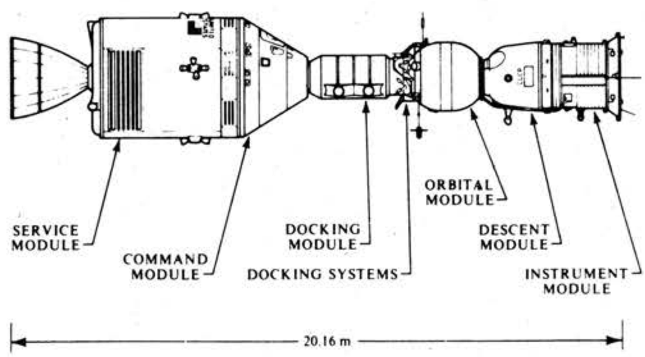
At initial contact, the three guides mounted on the guide ring (1 and 2) of each mechanism will align the spacecraft in the proper attitude for capture. Further spacecraft movement toward each other will operate three capture latches (3) to complete the intial docked position of the two spacecraft. The Apollo docking mechanism will then be retracted, drawing the structural rings (4) together. Eight structural latches (5) will automatically lock with the eight structural latches of the other mechanism. When the structural latches are locked, the two spacecraft are in the final docked position.

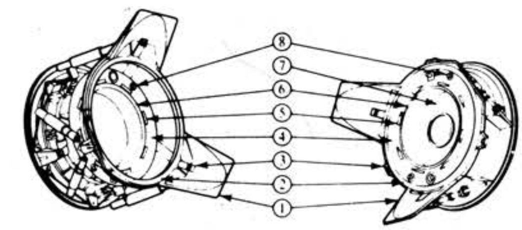
In this position, rubber seals of both mechanisms (6) will be compressed into each other. The internal pressure will be increased in the area of the seals and pressure checks will be made to insure there are no leaks.

After the structural and leak integrity has been confirmed, the internal pressure of the docking module will be adjusted to accommodate the crew transfers. This procedure involves the operation of the hatches (7) and life support systems of both spacecraft and the docking module. The systems are now ready for the crew transfers.

When the two days of joint mission activities have been completed, the two spacecraft will be configured for separation. The hatches will be reinstalled and the internal pressure vented.

Separation will be accomplished by unlatching the structural latches and the capture latches. The spring thrusters (8) then will separate the two spacecraft.





Key: 1. Guide; 2. Guide Ring; 3. Capture Latches;
4. Structural Ring; 5. Structural Latches;
6. Rubber Seal; 7. Hatch; 8. Spring Thruster.

National Aeronautics and Space Administration

Flight Crews

American astronauts named for the mission are Brigadier-General Thomas P. Stafford, Donald K. (Deke) Slayton, and Vance D. Brand. Stafford a veteran of the Gemini 6 and 9 and Apollo 10 missions, will command the Apollo CSM. Slayton, who will be 51 years old when the mission takes place, was selected as one of the original 7 Mercury astronauts but was grounded until last year because of a minor heart condition. His speciality is the new docking module. Brand, also making his first space flight, is command module pilot.

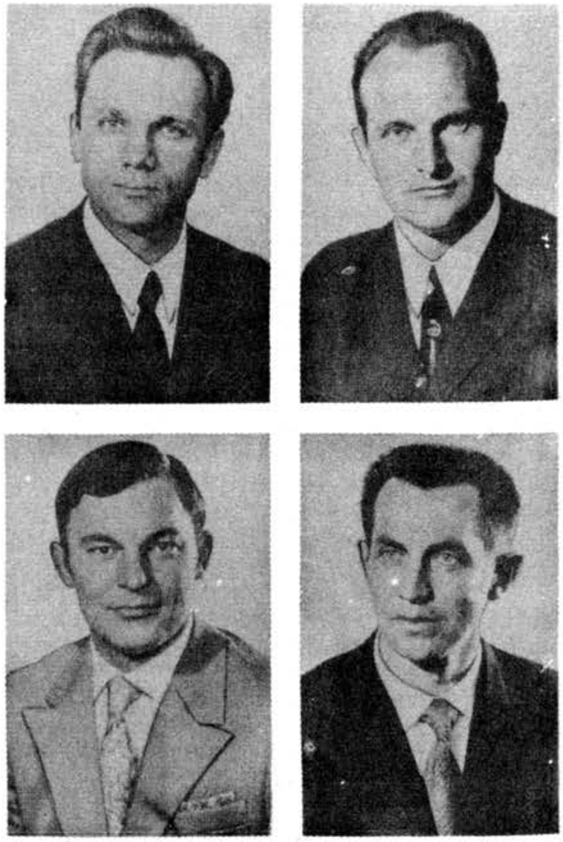
Backup crew for the mission are Skylab astronauts Alan Bean and Jack Lousma and Apollo 17 command module pilot Ronald Evans.

In contrast the Soviet Union is training four crews for the flight because, as Major-General Vladimir Shatalov* explained. two Soyuz spacecraft are being prepared for the mission. This is because Soyuz will be orbited first and Apollo 7½ hours later. No one could guarantee, he said, that Apollo would lift off precisely on time. It was necessary to take into account the possibility of a delay in launching or even, for one reason or another, failure to dock with the first Soyuz. The second

* *Cosmonaut training supervisor.*

Soviet ASTP cosmonauts. *First crew* (top, left to right), Alexei Leonov and Valeri Kubasov; *second crew,* Anatoli Filipchenko and Nikolai Rukavishnikov.

Novosti Press Agency



Soviet ASTP cosmonauts. *Third crew* (top, left to right), Vladimır Djanibekov and Boris Andreyev; *fourth crew,* Yury Romanenko and Alexanoer Ivanchenkov.

Novosti Press Agency

spacecraft would therefore be held in reserve ready for launching. It would be equipped with all the units and systems required for rendezvous and docking. So there must be two crews for each craft, the primary and a reserve adequately trained to carry out the exacting mission.

The first crew consists of Alexei Leonov and Valeri Kubasov, the second, Anatoly Filipchenko and Nikolai Rukavishnikenko, all of whom are Heroes of the Soviet Union.

The crew of the third will be Vladimir Djanibekov and Boris Andreyev, and of the fourth, Yury Romanenko and Alexander Ivanchenkov. *[Presumably these are back-up crews for the first and second flight respectively. Ed.].*

Col. Alexei Leonov was the first man (in March 1965) ever to walk in space, during the flight of Voskhod 2.

Valeri Kubasov was flight engineer during the Soyuz 6 mission in October 1969.

Col. Anatoly Filipchenko commanded the Soyuz 7 craft which took part in a group flight of three craft in October 1969

Nikolai Rukavishnikov was test engineer on an orbital flight in Soyuz 10 in April 1971.

The others have not been in space before.

Major Vladimir Djanibekov was born in 1942 in southern Kazakhstan, graduated from an Air College in 1965 as a pilot-engineer, and joined the cosmonauts' detachment in 1970.

Boris Andreyev graduated from the Bauman Technical College, joined a design bureau in 1965, and the detachment in 1970.

Capt. Yury Romanenko was born in 1944 in the Orenburg region, He graduated in 1966 as a pilot-engineer, and joined the cosmonauts' detachment (like the others) in 1970.

Alexander Ivanchenkov was born in 1940 in Ivanteyevka, near Moscow. After graduating from Moscow Institute of Aviation, he worked in a design bureau from 1964 until he joined the cosmonauts' detachment.

Leonov, Kubasov and Filipchenko, along with the American astronaut Thomas Stafford and officials of the joint USSR-US space pavillion, gave a press conference just before the opening of the Paris Air Show at Le Bourget where a full size exhibit of the Apollo-Soyuz could be seen in the docked configuration.

Alexei Leonov said that the first experimental joint flight in outer space, in 1975, was in keeping with the Soviet-American agreement on co-operation in the exploration and use of outer space for peaceful purposes. It would take a vast amount of design and technical work which was being undertaken by Soviet and American experts.

EVOLUTION OF THE SPACE SHUTTLE

By David Baker

NORTH AMERICAN ROCKWELL PART 3

[Concluded from July issue.

A New Specification

When NASA issued its work statement for initial Phase B Shuttle studies in the first half of 1970, the two prime contractors were instructed to develop a viable transportation system that could achieve full reusability, safely return both booster and orbiter, place a 25,000 lb. payload in a 240 nm, 55° orbit, and provide both 200 nm and 1500 nm cross-range capability.

The Space Division at North American Rockwell was already working on straight-wing and delta wing designs. In January 1971, NASA re-wrote the specification and opted for a delta-wing orbiter with 1500 nm cross-range capability, stipulating a 65,000 lb. payload to a 100 nm due east orbit, 40,000 lb. to polar orbit, and 25,000 lb. to a 277 nm, 55° orbit. This resulted in the configuration discussed in part 2 and displayed a funding profile far in excess of that acceptable to the Office of Management and Budget, the all-seeing eye of federal expenditure.

In the last quarter of the initial Phase B work for NASA, in an effort to simplify the system and reduce costs, provided supplemental funding for an examination of the external hydrogen tank orbiter. This resulted in a simplified orbiter design, a reduction in entry weight, and simplification of the booster. Staging velocities were reduced to the level where an all aluminium heat-sink booster became possible, reducing the gross lift-off weight, and lowering development costs to about $8,100 million with a peak annual funding of $1,700 million. Each flight would cost about $6 million, a 50% increase above the fully reusable internal propellent tank design of the initial configuration.

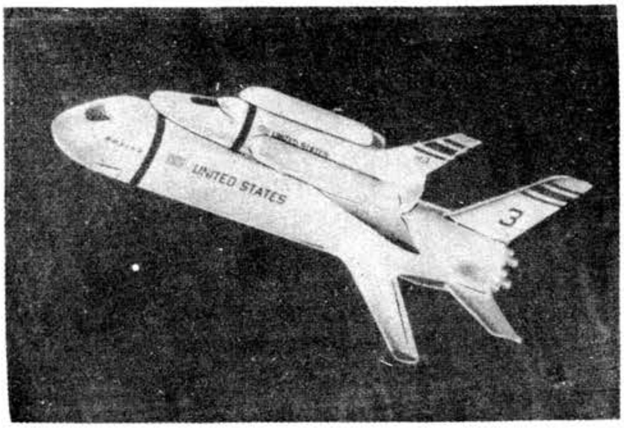
Further studies in a Phase B extension showed that additional savings would accrue if both the oxygen and hydrogen tanks of the orbiter were carried as external appendages, permitting the orbiter to be considerably smaller. In parallel with these studies the feasibility of adopting a 'phased' development plan was examined whereby an interim expendable booster would provide an early flight date, flattening the cost profile and anticipating later development of a manned fly-back booster. However, costing analysis failed to endorse this method as desirable and the space agency was channelled toward a recoverable unmanned concept for the booster.

The MKI/MKII

Meanwhile the orbiter programme had been examined and studies began to define a MKI/MKII approach. Under this concept a Mark I Shuttle with reduced capability would first be developed using less advanced technology and subsystems. As new technology and subsystems were developed they would be introduced some years later in a MKII Shuttle which would have the full planned capabilities. By this time development costs had fallen to the $6,000-7,000 million area and further cost reductions would stem from the adoption of an unmanned ballistic booster.

North American Rockwell briefed NASA on 1 September 1971 and 11 days later a redirection of effort was announced. The mandate? Fully define a new orbiter configuration and examine the alternate boosters: Pressure-fed, Re-usable S-IC, or 120 in/156 in. solid propellent stages in series burn where the orbiter is ignited at staging, or Pressure-fed, 120 in. or 156 in. solid propellent boosters in a parallel burn configuration with the orbiter firing off the pad in unison with its boosters. By this time propellent for the orbiter was relegated to a single tank to be attached beneath the fuselage.

The new orbiter configuration, known as the MSC 040A,



Grumman/Boeing external hydrogen tank space shuttle concept, August 1971.

provided a wing and fuselage shape, reaction control system location, attitude control requirements, and cockpit and airlock criteria.

The Space Division were to prepare their own detailed plans around this concept and make a booster selection by 1 November. Essentially of all-aluminium construction the orbiter was 110 ft. long, with a 74 ft. wingspan, weighing 124,000 lb and 130,000 lb. dry for the MKI and II variants respectively. The early model would use four J-2S engines, modified versions of the successful J-2 of Saturn launch vehicle fame, with four high-pressure engines in the MKII bringing the full payload capability to the Shuttle. The MKI would have a 500ft/sec. manoeuvre capability in orbit, increased by 100% for the MKII. Thermal protection on the MKI would be of an ablative type, necessitating a 55° entry with an L/D of 0.66. The RSI covered MKII would enter at 32° with an L/D of 1.4.

North American Rockwell applied Herculean efforts to the MKI/MKII problem and adopted a philiosophy from the onset that would permit a modification kit to turn any orbiter into the MKII. The alloy structure for both models would use a bondline temperature of 350°F but the ablative coating on the MKI would restrict the cross range capability to 200 nm. Thus a transition would be made when supporting technology could be funded for development of the advanced thermal protection, propulsion and avionics systems required for the MKII.

By the end of 1971 NR had drawn up some costing values for the different booster/orbiter configurations. In all cases, additional funds invested in the development phase would provide lower launch costs.

Of the series burn configuration, the Pressure-fed system would cost $9,740 million, $8.10 million to launch and require a single-year peak of $940 million and the Reusable S-IC system would cost $9,910 million and drive launch costs down to $5-6 million. But here the peak annual requirements of $1,230 million showed it to be less competitive. Best of all were the solid propellent parallel burn designs, presenting a development bill of some $5,500 million with a launch cost of $10-12 million.

First Phase B Extension Results

The orbiter design would incorporate much of the technology of existing programmes. The propellent tank would conform to design requirements closely following those of the S-II, second stage Saturn V. Some 128 ft. long, with a diameter of 25 ft. the external tank would be pressurised to 56p. s.i. ULT, only 27% greater than the S-II. The selected material, 2219-T87 aluminium, was very similar to that of the S-II and permitted 5 low pressure and 2 high pressure cycles.

Throughout the orbiter itself the structure was well within current state-of-the-art and gave promise of an economical development phase, somewhat less sophisticated than the earlier concept but considerably more practicable. In comparison with aeronautical projects the Shuttle finds a parallel with projects such as the DC-10, XB-70, and the B-1. Load factors, design temperatures, and materials are all similar and the design lifetime is considerably less than for contemporary aircraft. However, due to the propulsive factors the subsystems are very sensitive to growth in weight. An increase of 11.9% in the 33,000 lb. fuselage structure will decrease the polar payload by 10%, whereas environmental control, avionics, auxiliary propulsion and electrical power subsystems could all grow by 70-250% before picking up the 10% payload penalty.

Factors such as this are important drivers in the case for controlling weight growth and NR's previous programme experience shows an interesting statistic. When a correlation is made between the X-15, X-20, Mercury, Gemini and Apollo spacecraft the average weight growth, including design changes and requirement changes, becomes 15% of the baseline value. To combat this NR have built in a 10% margin with a 10% weight growth factor beyond this. The weight growth can be accompanied by simply increasing the propellent tank capacity and as such is a very forgiving design.

In the main propulsion area the orbiter becomes highly sensitive to changes in engine performance. Using payload weight as a performance parameter it is found that a 1% divergence from the nominal Isp will affect the lifting capability by 2,500 lb. Yet, generally Isp values are projected on the conservative side and the development histories of the F-1, J-2 and RL-10 reveals an average 1% plus of performance. Breadboard tests of the Space Shuttle Main Engine itself gave justification for anticipating a 2% increase on Isp with production engines, equivalent to a weight growth of 8% in the total configuration.

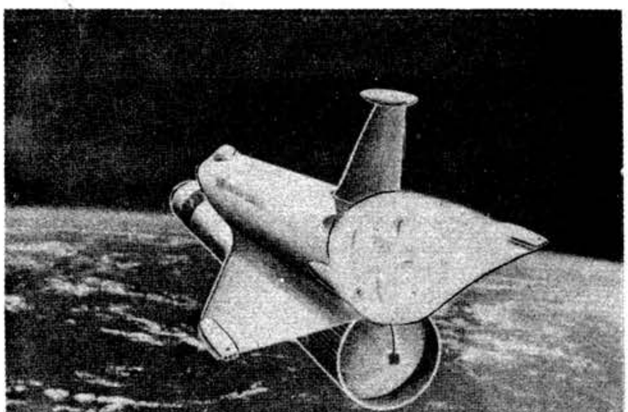
In summary, the design team were highly confident that conservative estimations of payload capabilities reflected from structures, weight growth, and propulsion, could increase the payload to orbit by some 60%, or 23,000 lb. above the specified polar capability.

In the subsystems area confidence was high that programme costs and schedules could be met with good margins. In attempting to decide the avionics issues, twelve formal trade studies were conducted to determine the optimum approach, compare results with the baseline, and estimate inherent risks. The conventional analog and digital techniques used in Apollo would be followed into the Shuttle and as much as 63% of this area is provided from currently available hardware. Operating on a fail-operational, fail-mission, fail-safe, criteria the orbiter provides for manual override in the event of failure, a real-time 'black-box' recorder, and a separate return-to-Earth system. Less sophisticated than the prime guidance mode the RES provides the capability for a man-safe flight to the ground.

The ability to handle future requirements is provided by 100% margins for software and modular components to avoid interaction.

Environmental control and life support equipment provides a shirt sleeve environment for 6 crew members, removes and purifies CO_2 and odour, stores and provides food preparation, and collects and stores body waste. Adopting what is basically an Apollo-type system the ECL-SS differs mainly in providing a mixed-gas N_2/O_2 atmosphere at 15 p.s.i. Mission duration, heat sink approach and cabin temperature control are all very similar to the command module, dictating a similar specification and providing an easy transition at low cost.

Electrical power is supplied from three Apollo-type fuel cells, with redundancy permitting the same triple failure in any one system. The reactants (LH_2 and LO_2) are stored in four dewars with physical separation of redundant sources to prevent the propagation of a major failure. Mechanical power is provided by four independant monopropellent hydrazine APU's, selected on the basis of minimum cost and less risk than an H_2/O_2 system. Considerable work remains to be done in this area before the concept is flight ready.



Single external LO_2/LH_2 tank for orbiter engines (booster mounted beneath tank having jettisoned).

National Aeronautics and Space Administration

Orbiter Propulsion

Propulsion for the orbiter was provided in four major subsystems: Main, Air-Breathing, Orbit Manoeuvre and Auxiliary or attitude control. By this time, late 1971, the NR orbiter had conformed to NASA's demands in deleting one of the main engines. Months earlier, when NASA was thinking in terms of a MKI/MKII approach, the high pressure engines for the definitive version were to be rated at 265,000 lb. thrust, minimising the transition from the earlier J-2S of comparable power. By this time it will be remembered the booster had been deleted in favour of a conventional launch stage, thus eliminating the higher thrust rating required for this vehicle.

The main propulsion system of this modified MSC040A design comprised three motors rated at 450,000 lb. thrust mounted on the thrust structure and canted above the centreline. The air-breathing engines chosen were the F401-PW-400 series, selected for their low weight and smaller diameter. On-orbit manoeuvres would be performed with 4,800 lb. thrust motors mounted one either side of the upper main propulsion

unit using a mixture of nitrogen tetroxide and monomethyl hydrazine as propellent. Attitude control would be achieved through 34 x 950 lb. thrusters located in pods on each wing tip and on the tip of the fin. Propellent was anhydrous hydrazine and served to control roll, pitch and yaw translations as well as minor manoeuvres such as station-keeping and docking.

Thus was the orbiter design hardened in February 1972 in readiness for an Office of Manned Space Flight review. But the booster options were still wide open. NR selected a pressure-fed liquid propellent series-burn design, and a solid propellent parallel configuration for detailed analysis.

The pressure-fed assembly comprised a 150 ft. long, 26 ft. diameter booster with seven engines attached at the base and supplied with a LOX/RP-1 propellent. Each engine would stand 17 ft. tall and develop 1.04 million lb. thrust before separating at staging and falling to an ocean splashdown at 150ft/sec. Above the booster would be the 146 ft. propellent tank for the orbiter, with the latter attached to the side of the pod. At launch the total stack would weigh 6.505 million lb. and provide a thrust of 7.280 million lb. standing 296 ft. tall.

The alternative to this was the solid propellent parallel-burn configuration. This concept would use two 13 ft. diameter shells composed of segmented steel cases fabricated from shear spun D6a C steel standing 157 ft. high. A 186 ft. tall propellent tank would be located centrally between these boosters, an increase from the pod used with the pressure-fed booster arising from the parallel burn concept and a greater propellent requirement. Thrust vector control would be accomplished through a hydraulically actuated moveable nozzle. At this time recovery of the boosters was not anticipated.

Of the two concepts for boost the SRM design would achieve a high velocity before staging: 5,333ft/sec. versus 4,800 ft/sec. of the pressure-fed booster. This would ultimately weigh heavily in favour of the SRM design and relieve a fraction of the orbiter's load during ascent.

It was on 15 March 1972 that NASA decided to select the recoverable SRM concept for the Shuttle and two days later the agency released RFP's for the orbiter and total programme integration. The design submitted by the Space Division was essentially the same as that derived earlier in the year and described above. The only major configurational change was to re-locate the attitude control pods from their wing and fin locations to fuselage positions.

Late in July the years of hard work and determination paid off. The Space Division were awarded a $2,600 million contract for Shuttle development. We will now look at that design as it stood in September 1972.

The ATP Baseline Design

The orbiter portion of the NR Shuttle is sized for a 60 x 15 ft. cargo bay capable of carrying a maximum 65,000 lb. payload, with a crew of two and a 10 person accomodation in the crew compartment. It has a length of 125 ft. 9 in., a span of 84 ft. and a height of 57 ft. when standing on its landing gear.

The wing, a modified 0008-64 aerofil, is fabricated from aluminium, with corrugated web main beams, truss-type ribs and riveted skin-stringer covers providing an exposed planform of 2,203 ft^2. The 50° delta shape has a quasi-ogive profile with a 3.5° dihedral at the trailing edge. A 3° root wing twist at the fuselage fillet is transformed into a negative 2° at the tip. The centre fuselage section carries lower surface loads through a lower skin, upper loads being carried by concentrated spar caps. Frame attachments double as wing shear load transmitters.

The fuselage is divided into three major subassemblies: forward section, mid-section and aft section.

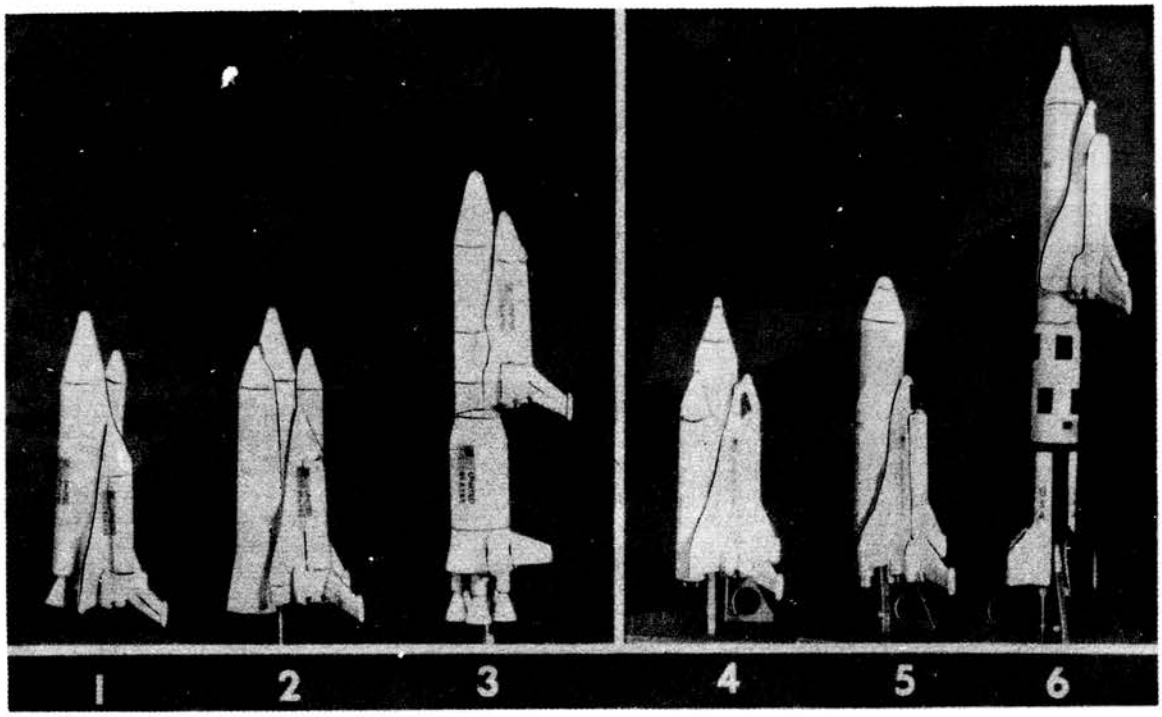
The forward fuselage consists of an integral cabin structure of machined 2219 aluminium alloy plate with integrally stiffened stringers and attachment bosses for internal framing of all-weld construction to ensure a pressure-tight vessel. The forward section itself is formed from a stringer-frame assembly with an outer shell of 2024-T-86 alloy. The forward landing gear is retracted into this section, similar to the attitude control thrusters when not in use.

The mid-section fuselage carries the main wing beams and accepts all lateral loads for straight-through damping, supporting the cargo bay floor and sidewall structure. Thirty-three formers are equally spaced down the length of the bay to support the aluminium skin and upper door attachments. The non-structural cargo bay doors are made up from conventional skin-stringer design, hinged along each side and split at the top centreline. Each door is made up of four segments to prevent bending stresses transmitting through the panels.

The aft section consists of machined plate and bar truss-type internal structure and is primarily responsible for carrying the thrust loads from the main engines and supporting the vertical tail. The structural design permits the location of numerous panels and removable doors for access to the propulsion systems carried by this section. The tail itself is a two-spar, multi-rib, stiffened skin box assembly attached to the aft section by bolted fittings at the spars. The rudder is in two sections and split for speed brake use with each section hinge-mounted for the dual role. The vertical tail has a 435 ft^2. area with the rudder presenting a 118 ft^2. and a ± 15° deflection or a 70° included angle for use as a speed brake. A base heat reflector projects the external propellent tank from expansion chamber temperatures and is hinged to provide clearance on landing.

Thermal Protection

Thermal protection for the orbiter is the most demanding area of Shuttle design and a considerable amount of work has been devoted to selecting an ideal combination for minimum weight and maximum protection whilst providing minimum maintenance and turnaround time. The maximum equilibrium temperatures to be experienced occur on entry with maximum heating on the underside of the extreme nose, the forward undersurface panels and the wing leading edges. To combat the near-3,000°F expected in these areas the Space Division have selected a Reinforced Carbon-Carbon material, chosen for its comparatively low weight, reasonable cost, and good criteria for reusability. The leading edge and nose cap sections are a compromise between aerodynamics and RCC material design. The latter exhibits a reuse sensitivity proportional to the shape versus temperature ratio. The entire upper section of the centre fuselage, the aft fuselage section and much of the upper wing area is exposed to temperatures between 650°F and 2,500°F. A ceramic Reusable Surface Insulation (RSI) is used for these areas. In consists of a ceramic fibre and binder matrix bonded to the vehicle's airframe through a foam pad in panel sizes ranging from 8 to 20 in. A ceramic outer coating provides waterproof protection, pigmented for protection during orbital operations. The undersurface of the foam pad is base-lined at 350°F. Vent lines between panels permit a degree of outgasing and allow thermal

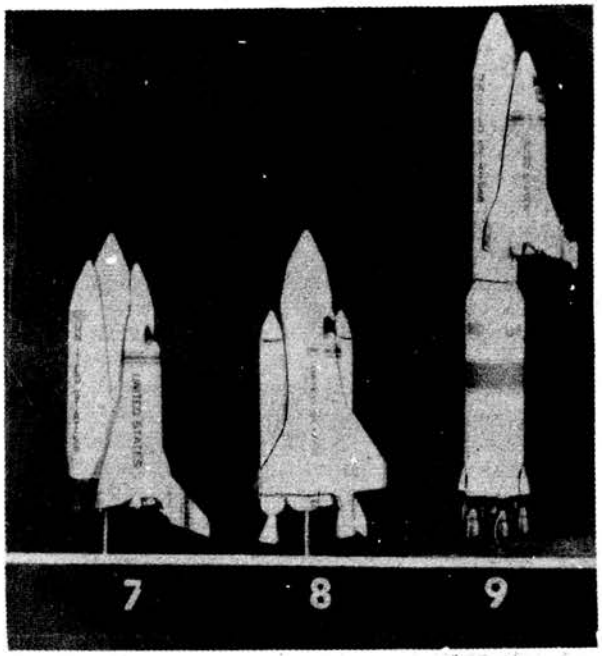


Proposed NASA space shuttle concepts with manned re-usable orbiter, January 1972.
McDonnell-Douglas Corporation/Martin Marietta:
1. Expendable solid-fuelled rocket booster
2. Recoverable liquid fuelled booster.
3. Recoverable liquid fuelled booster.

North American Rockwell/General Dynamics:
4. Recoverable liquid fuelled booster.
5. Expendable solid fuelled booster.
6. Recoverable booster and manned reusable orbiter.

Grumman Aerospace Corporation/Boeing Company:
7. Recoverable liquid fuelled booster.
8. Expendable solid fuelled booster.
9. Recoverable unmanned booster and manned orbiter.

National Aeronautics and Space Administration



expansion to cover the exterior under maximum heating. The maximum thickness of foam/ceramic RSI covering – nearly 3 in. deep – is required on the underside of the nose.

Other areas, including the sides and top of the forward section, the wing/fuselage fairing, elevons, rear propulsion pods and tail assembly will never experience temperatures greater than 650°F. For this an elastomeric RSI has been selected. Applied in 24 to 36 in. panel sizes the methylphenol silicone is bonded directly to the airframe and provides in-orbit insulation as well as entry protection. The same pigmented covering is provided for protection. In general the material is applied in 0.4 in. uniform thickness.

The main propulsion system for the orbiter consists of three 470,000 lb. vac-thrust rocket engines mounted to the thrust structure in the aft section of the fuselage. They serve to provide velocity increments for ascent to orbit and also for several abort modes. Each of the three engines operates at a mixture ratio of 6:1 and a chamber pressure of 3,000 p.s.i. compared with 980 and 780 p.s.i. respectively for the F-1 and J-2, the powerplants of the Saturn V. The high chamber pressure, bringing a first order advancement to chemical propulsion, provides a vacuum Isp of 455.2 lb-sec/lb. and 363.2 lb-sec/lb. for a 375,000 lb. thrust at sea level. Each engine is throttleable over a range of 50 to 109% of design thrust allowing limitations to be imposed on acceleration and providing high levels for abort. The engines can be gimballed ± 11° for pitch, roll and yaw control during the boost phase to orbit.

Five fluid lines carry propellent from the external tank, interfaced through self-sealing disconnects on the underside of the engine compartment, three of which supply LH_2 and two LO_2. Most of the components have been located in the orbiter to eliminate expendables with the tank. Dry weight of the engines and propellent feed system is estimated at 45,980 lb.

The orbital manoeuvring system provides velocity increments for orbit circularisation, transfer, rendezvous and deorbit. Two identical propulsion pods are attached to each side of the rear fuselage, providing 1,000ft/sec ΔV with a 65,000 lb. payload in the cargo bay. Each pod contains a high pressure helium bottle, tank regulators and controls, a 7,220 lb. tanked supply of monomethyl hydrazine, a 4,960 lb supply of N_2O_4, and a pressure fed regeneratively cooled rocket engine of 5,000 lb. thrust. The chamber pressure for this engine is 120 p.s.i. with an Isp of 308 sec. In addition, up to three auxiliary tanks can be installed in the aft portion of the cargo bay, providing an extra 500ft/sec. per tank, thus increasing the total potential ΔV available to 2,500ft/sec. Propellent is dumped through two rear vent tubes prior to re-entry.

Attitude control and propulsion for small translational manoeuvres is provided for by 40 monopropellent thrusters. Each thruster operates at a chamber pressure of 150 p.s.i. and with a nozzle ratio of 20:1 develops an Isp of 230lb-sec/lb. at 1,000 lb. thrust. The thrusters are grouped in four assemblies; one each either side of the nose and two either side of the rear fuselage attached to the orbital manoeuvrepods. In each nose assembly a retractable door is deployed to expose eight thrusters, two of which face forward, two laterally, two up, and two down. Both panels are supplied from five hydrazine tanks in the extreme nose, pressurised from two helium tanks. In the rear pods, each unit is self contained and carries its own propellent supply. Three thrusters face up, three face down, two point to the rear, and four point laterally across the wings. Three hydrazine tanks are provided for each module, with a single helium vessel isolating port and starboard units. Some 7,280 lb. of usable hydrazine is stored in the orbiter, with a total system of 10,307 lb.

These three propulsion systems are all that is required for effectively completing a full mission profile. However, additional propulsion must be carried if the orbiter is ferried from site to site or tested in the atmosphere for horizontal flight. Known as the Air Breathing Propulsion System (ABPS), the assembly consists of four F 401-PW-400 engines mounted on pylons and situated around the top rear section of the cargo bay. For ferry tasks the rear mounted orbital manoeuvring and attitude control pods are moved and a fuel tank added to the lower section of the rear cargo bay. With this additional equipment the orbiter has a 400 mile ferry range.

In the event of an abort during ascent the orbiter would be separated from the boosters and external propellent tank by two ASRM assemblies, a space acronym for Abort Solid Rocket Motor. Each of these is 31 ft. long with a diameter of 5 ft. 6 in. and a total system weight of 99,050 lb. They were to be jettisoned on the ascent. (The ASRM's were later deleted. Ed.).

An hydraulic system is required for actuation of the flying controls, engine gimbal, landing gear, steering, and engine shield. Four independant systems are carried by the orbiter, providing a high level of redundancy, minimising weight and logistics. Each system is powered by two variable displacement pumps from separate APU's satisfying fail-operational, fail-safe criteria. Each APU provides 200 horsepower to the hydraulic pumps and ac generators for 90 minutes. Low pressure fuel tanks holding 1,986 lb. of hydrazine supply fuel to each APU, with all modules attached to quick-release doors for ease of servicing on turnaround. With the modules removed access is gained through a 30 x 30 in. hatch onto an unobstructed walkway. The auxiliary power and hydraulic pumping equipment is all grouped around the upper fuselage to the rear of the cargo bay.

The avionics equipment, installed for providing guidance, navigation, communication, computation, displays, controls, and instrumentation, is housed in the crew compartment, the forward avionics bay and the aft avionic equipment compartment. Automatic flight control is provided for all functions except station keeping and docking, with manual options preserved at all times. Status monitoring and information on performance, and operational readiness, is fed direct to the flight deck for crew decisions on mission procedure. A new wire system, known as Circuit Design, Fabrication and Test Data System, or CDF & TDS, was proposed for the design, fabrication and wire validation testing for the orbiter. This is a new concept pioneered by North American Rockwell and establishes a single common data base from which all wire lists, manufacturing tickets, cable designs and validation tapes are derived.

Guidance and navigation is installed to provide automatic and manual control of all mission phases, guidance and steerage of control loops and servo systems, and inertial navigation derived from star and horizon sensors. Three independant and redundant sets of components are provided for a full fail-operational, fail-safe capability. Body mounted rate gyros and accelerometers provides the ASAS with aerodynamic stability augmentation and conventional stick rotation controllers and rudder pedals permit manual control. Guidance and navigational imputs are derived from horizon and star trackers for automatic alignment and state vector update. Range information is derived from TACAN. Landing approach and flare-out is accomplished via a computer path with the inertial platform used for references updated from TACAN and ILS's.

Data processing and software is supported by a guidance and navigation computer and modular display electronics, the interface between the computers and vehicle systems being modularised for continual updating or periodic renewal.

The communications and tracking elements provide RF voice, command, and data transmissions, tracking for rendezvous, and navigational inputs for aerodynamic flight. Telemetry commands, voice, TV, and payload relays are linked to the Space Tracking and Data Network via compatible transponders in the orbiter. S-band communication is effected through a wideband S-band transmitter, STDN and SGLS transponders, two signal processors, four USB/SGLS decoders, and two signal interrogators. VHF communication is routed through two VHF/AM & FM transceivers and two control decoder on a two-way interface with the audio centre and distribution module. RF navigational aids include ATC L-band transponders, TACAN and ILS equipment and three radar altimeters.

Operational flight instrumentation provides the interface between major vehicle subsystems and recorders and display units. The adoption of PCM master/PCM combinations reduces weight and wiring complexity and controls remote sampling rates and subsequent storage.

Electrical power for the orbiter is provided by three LH_2/LO_2 fuel cells located below, and at the forward end,

of the cargo bay. They are required to provide a continuous power output of 7kw, and a peak of 10kw, and voltage range of 27.5-31.0 dc. Cryogenic liquids are stored in four pressure vessels secured to the underside of the cargo bay and forward of the wings. The two 19.2 ft^3. hydrogen tanks contain a total 166 lb. of LH_2, stored at 250 psia in a double skinned pressure vessel fabricated from Ti-5AL-2.5 Sn ELI. Much of the Apollo fuel cell technology has fed across to the Shuttle and the heaters are retained for ensuring nominal pressure. Two 10.4 ft^3. Inconel 718 vessels store the 1,434 lb. of LO_2 at a pressure of 1,050 psia, with paired LH_2/LO_2 tanks secured to either side of the fuselage ensuring redundancy in the event of a rupture disabling either system. Supplementary power is obtained from three 20/30 kva, 400-H_2 generators powered by the turbine driven APU's for all ascent, entry and landing phases. In addition, pyrotechnic devices are powered from two 10 ampere/hr nickel-cadmium batteries housed in the forward fuselage.

Electrical distribution is provided by three 28 vdc buses and 115/200-volt, 400-H_z main and inverter dc buses. Each bus is isolated to prevent complexity and to facilitate redundancy with the three generators feeding the main ac bus, and the fuel cells on the dc line.

Atmospheric and environmental control must support many functions. Among these it must provide a controlled O_2/N_2 pressure at 14.7 psia, a cabin temperature between 65° and 80°F, adequate food storage and preparation equipment, waste liquid and faecal storage, an active N_2 purge fire suppression system, and an equipment and vehicle thermal control system. Most of the support equipment is contained in the forward fuselage, surrounding the pressure cabin and easily accessible for maintainance. Oxygen is taken directly from the cryogenic fuel cell vessels, and nitrogen is stored at 3,000 p.s.i. in the centre fuselage. Humidity control, CO_2/odour control and temperature control is facilitated by three two-speed fans, two lithium hydroxide canisters, a heat exchanger and a bypass valve, respectively.

Two thermal control loops are installed. One for the cabin area uses water as a coolant and the loop for the unpressurised areas uses Freon-21, interfacing with the fuel cells and hydraulic systems. The radiators are carried on the inward facing surface of the cargo bay doors, hinged at the door-attachment line, and deployed with the doors to lift free by several feet when the panels lie parallel with the wings. Some 11,000 ft^2. of effective radiator area is exposed on the upper surface, with 400 ft^2. area in the under-surface. The double sided radiators are used throughout all on-orbit operations with a water sublimator providing a heat sink during boosts. For atmospheric cruise regimes the ram air heat exchangers accept thermal loads from vapour-compression cycle refrigeration systems. These latter units are housed in the rear fuselage directly beneath the tail.

The payload compartment, or cargo bay, is designed to accept a 60 x 15 ft. payload, and provides support services in the form of a remote manipulator, control and display of pertinent payload characteristics and a man-monitoring station in the aft section of the crew compartment. Any two of three payload-stations must be manned at all times, with a visual display readily available of the payload. Within the cargo bay itself a retention cage ensures the isolation of orbiter stresses and prevents the transmission of loads to the contents of the bay. The remote manipulators are double armed with a single 'elbow' joint mid-way along the arm. Both sections are folded into a 'spine' that runs along the cargo bay door join line when the latter are closed. RF links, fluid supply, gaseous supply, and vent lines are all plumbed in for supporting the requirements of payloads.

The area immediately forward of the cargo bay houses the airlock and re-charge stations for portable life support systems. The cargo bay itself is unpressurised and extravehicular excursions are planned for payload inspections, data-tape retrieval, and general duties within the bay.

The flight crew are provided with two forward facing, pilot/co-pilot control and display stations, and aft-facing payload station, a mission specialist station for payload management and power distribution panel in a lower well on the deck. Manual controls are provided, including rotation and translation hand controllers, rudder pedals, speed brake controls, thrust control, and air-breathing engine throttle controls.

The basic NR orbiter, as conceived for the Authorisation To Proceed in August 1972, topped a gross weight of 277,500 lb, presented a dry weight of 170,000 lb. and possessed a landing weight of 215,100 lb. Of the gross weight, some 33,400 lb. of propellent was carried for the orbital manoeuvring and reaction control motors.

When NASA decided to adopt an external propellent tank configuration for the Shuttle the orbiter became little more than an aerodynamic cargo tube, half the original size and considerably simplified for all flight regions. However, a new structure was required to contain the propellents for the three high-pressure engines in the rear of the fuselage and this brought design problems all of its own. The volume of propellent required for the ascent would dictate the size of the tank and give the Shuttle its largest component by size.

The tank configuration for the ATP baseline design was 182 ft. long and 26.5 ft. in diameter.Within the cylindrical outer structure the tank contains two propellent vessels. Both are fabricated from 2219 aluminium alloy with support frames positioned at intervals along the entire length. The sidewalls and end bulkheads use the largest available width of plate stock with the skins butt-fusion-welded to present maximum sealing. The intertank structure, separating the forward LO_2 tank from the aft LH_2 tank, is of semi-monocoque type with monocoque sidewalls on the oxygen tank. Integrated Y-frame assemblies are used on the forward and rear domes of the LH_2 tank, a legacy from the S-II stage design.

Structural attachment of the tank to the orbiter is achieved through a single forward and two rear connections consisting of truss mounted supports for the latter. Thermal protection is afforded by spray-on foam insulation applied to the entire outer surface including the aft bulkhead. The nose cone is covered in a cork ablator bonded directly to the alloy skin and a similar treatment is applied to the intertank structure. This heat sink approach is made possible by the conservative thermal build-up during the low acceleration ascent.

All fluid controls and valves for the main propulsion system are carried within the orbiter to minimise the expendables and only propellent feed lines, pressurisation valves, and vent ports are located on the tank. The extreme nose of the tank as originally conceived, was to have a small solid propellent motor for de-orbiting the tank, housed within a frangible nose cap and pointing in the forward direction for retrofire (subsequently it was decided to release the tank just before the orbiter attains orbital velocity and thereby dispense with the retro-rocket. Ed.).

At launch the total weight of the tank is 1,782,000 lb. with 1,715,007 lb. of propellent contained within the 21,246 ft^3. LO_2 and 58,631 lb. LH_2 vessels. Normally about 1,696,895 lb.

of LO_2/LH_2 would be used during ascent with a 3% ullage margin budgeted in the consumption profile. The oxygen and hydrogen tanks are pressurised to nominal values of 21 and 36 psia respectively with a 6 p.s.i. overload relief factor. By weight alone the external tank contains 1,467,443 lb. of LO_2 and 247,564 lb. of LH_2.

The Solid Rocket Motors

When NASA decided to adopt a parallel burn solid rocket motor (SRM) configuration for the Shuttle industry had not had the opportunity to appraise this concept in the same depth as that applied to external propellent tank orbiters, and at the post-contract award briefings the SRM design was still in a state of flux.

However, the proposed boosters were 184.75 ft. in length, with a 13 ft. diameter and comprised motors, nozzle, case and propellent, with igniters, arming devices, and thrust termination systems attached to the specification. Each SRM contains 1.415 million lb. of PBAN (Poly-Butadiene-Acrylo-Nitrile) propellent and produces 4.13 million lb. of thrust at sea level, reducing to 2.6 million lb. 40 seconds after lift-off, constrained by the shape of the propellent grain. Grain design is of the starred perforation type in the forward section, and the truncated cone form in the segments and aft close-out area. The motors operate to a specific impulse of 243lb-sec/lb. ar sea level and 276lb-sec/lb. at altitude; chamber pressure is 932 p.s.i. and expansion ratio 1:13.

The segmented design of the SRM affords ease of fabrication and facilitates transport from the manufacturing site to the assembly area. Two symmetrical ports located in the walls of the forward segment comprise the thrust termination system with redundant linear shaped charges integral with the forward dome. The SRM support struts at the rear mate with aft attachment points on the external tank, comprising four linkages with triple redundancy on activation and release. A rear support frame is installed around each SRM to react side loads between the boosters and the external tank, with lateral sway braces and a slide device providing positive attachment. A single ball joint at the forward end of each SRM enables a pyro-clamp to hold the SRM's flush against the side of the external tank. Parachute and recovery devices are also housed in this forward thrust cone structure.

Separation of the boosters from the tank/orbiter configuration is effected by pyrotechnic devices at the extremities of the sway braces and slide attachment points.

Avionics, comprising electrical power and distribution systems, a malfunction detection system, and sequential starters are clustered in the forward segment, together with batteries, four separation thrusters, and ordnance systems. The recovery of each SRM is an important factor in achieving creditable economics and a mortar deployed 9 ft. ribbon pilot parachute initiates deployment of the recovery system, followed by a 66 ft. drogue and finally three 110 ft. main parachutes with two stage reefing and dual redundant line cutters. A flotation collar attached by frogmen after splashdown facilitates towing and recovery operations.

The gross weight of the two SRM's is 3.252 million lb. with 2.829 million lb. of propellent consumed during the 109 seconds flight. Each SRM has an inert weight of 212,000 lb. of which 11,000 lb. is devoted to recovery devices.

Three major elements of the Shuttle (orbiter, external propellent tank, and solid rocket boosters) gave the configuration of gross lift-off weight of 5.410 million lb. and a combined launch thrust of 9,385,000 lb. At booster separation the orbiter/external tank combination is to be accelerated under the 1.410 million lb. thrust of the three main engines. The total length, primarily dictated by the external tank, would be 202 ft. 3 in. with an overall width across the wings of 83 ft. 11.7 in. and a maximum spread across the booster nozzle plane of 66 ft. 8 in.

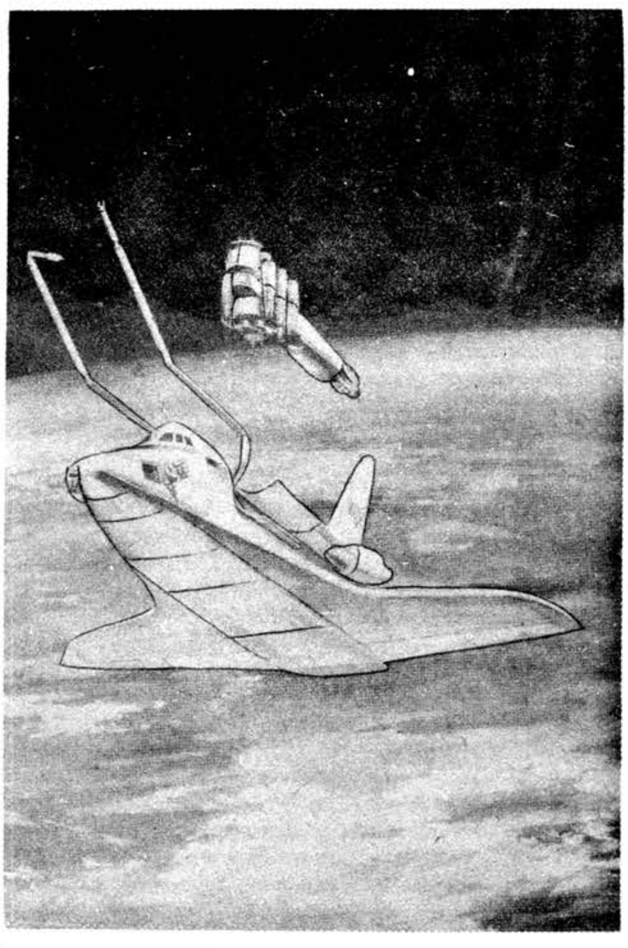
Payload Considerations

The payload capability was sized for a 40,000 lb. delivery into a 100 nm polar orbit with manoeuvring criteria and orbital changes dictating the auxiliary propulsion requirements. With no additional OMS tankage in the cargo bay the Shuttle promised a 65,000 lb. delivery capability into a 100 nm, 28.5° orbit. Removing the cargo bay design limit of a sustained 3g acceleration would permit a realistic 74,000 lb. lift to this orbit. Raising the altitude to 240 nm would degrade the payload value to some 62,000 lb. and an additional OMS tank would permit a 51,000 lb. load to be transported some 350 nm in altitude. Second and third auxiliary tanks would raise this to 40,000 lb. at 460 nm and 24,000 lb. at 570 nm respectively.

For 55° inclination orbits the basic orbiter could lift 38,000 lb. to 270 nm, 25,000 lb. to 370 nm with one OMS tank, or 10,000 lb. to 490 nm with two. Polar orbits would

Latest configuration orbiter releases a large satellite with attached propulsion unit.

Rockwell International



permit a 40,000 lb. payload to 100 nm, or 27,000 lb. to 270 nm. One OMS tank in the cargo bay would raise this capability to 13,000 lb. at 405 nm, or a maximum 800 lb. to 500 nm.

Mission Profile

A typical Shuttle mission, using the basic hardware discussed in the previous section, begins with ignition of the three orbiter engines and the two solid rocket motors, with a release for flight when T/W=1.0. The roll and pitch manoeuvres are begun some 5 seconds later when the Shuttle clears the 280 ft. launch umbilical tower.

If an abort should become necessary the solid boosters are jettisoned to release the orbiter for glide-back to the landing strip or, in the event of a malfunction with the external tank, a release by aerodynamic force. A secondary mode of abort would carry the orbiter/tank to orbit with recovery on a subsequent revolution.

Max Q is experienced some 56 seconds after lift-off at 35,000 ft. and 1,313 ft/sec with a pressure of 650 lb/in^2. on the vehicle. Staging occurs at 130,312 ft. some 1 min. 49.1 sec. after lift-off at a velocity of 4,035 ft/sec. Eight solid thrusters push the boosters away from the tank and start them on a ballistic trajectory to an ocean impact. Drogue parachutes are programmed to deploy at 32,000 ft. 3 min. 18 sec. later, at a velocity of 1,123 ft/sec. The main parachutes deploy at 10,000 ft. 4 min. 1 sec. after separation, at a velocity of 340 ft/sec. Seven minutes and 11 seconds after separation the two boosters splash into the Atlantic 112 nm downrange at a velocity of 86.5 ft/sec.

Guidance steerage on the ascending orbiter is brought in at an altitude of 177,000 ft. only seconds after booster separation and the three main engines continue to burn for a total duration of 9 min. 11 sec. Shut-down comes at an altitude of 50.7 nm with the vehicle travelling at 24,494 ft/sec. From this point the orbiter will coast on up to an apogee of 100 nm but shortly after shut-down the external tank is separated and de-orbited by the small solid rocket motor in the extreme nose for an ocean impact 58 minutes after launch and 10, 512 nm downrange.

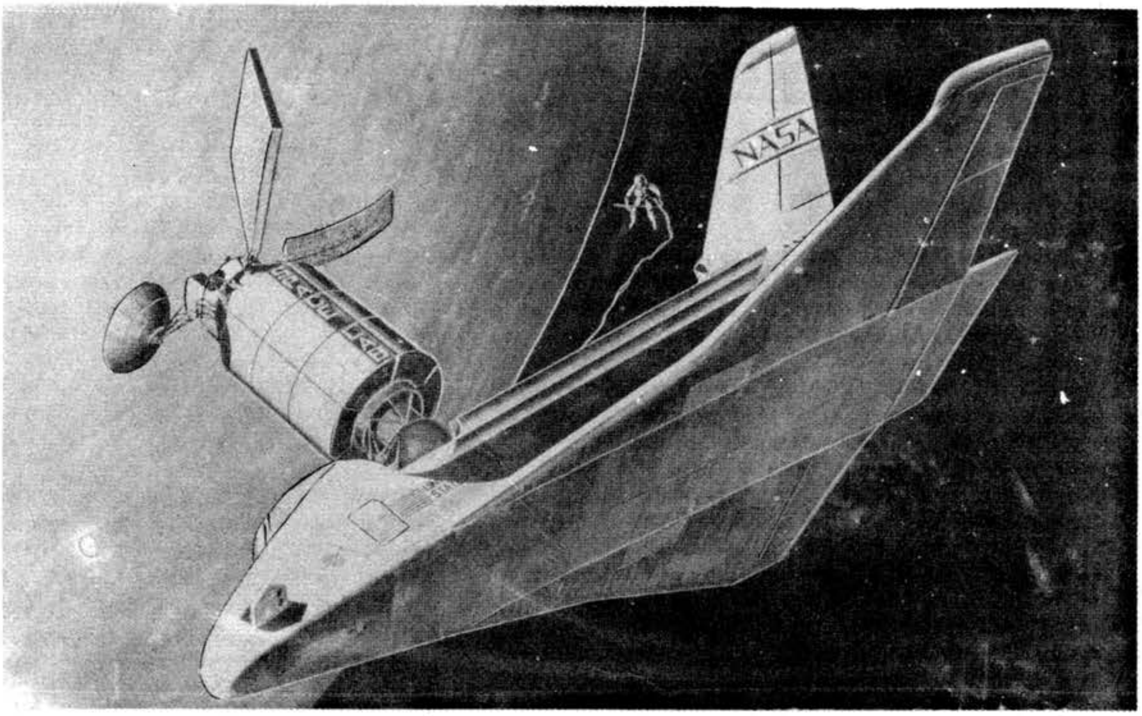
At apogee the two orbital manoeuvre engines inject the orbiter into a 100 nm circular orbit, raising the perigee only after a full systems checkout has pronounced the vehicle operational. In the event of a detected malfunction prior to circularisation the orbiter would descend to its 50 nm point where a reaction control system burn would start it on a descent to Earth.

After a nominal stay in orbit the OMS engines fire a 228 ft/sec. retrograde manoeuvre to return the vehicle. Entry is effective at an EI gamma of 0.91° and an incidence of 34° at 25,604 ft/sec. with an L/D of 1.32. At 50,000 ft. the orbiter provides for either 1,085 nm cross-range or 4,700 nm downrange capability with a touch-down on the 10,000 ft. runway at 150 knots and a maximum incidence of 18°. Unpowered landings would be standard on all atmospheric glides from an orbital mission.

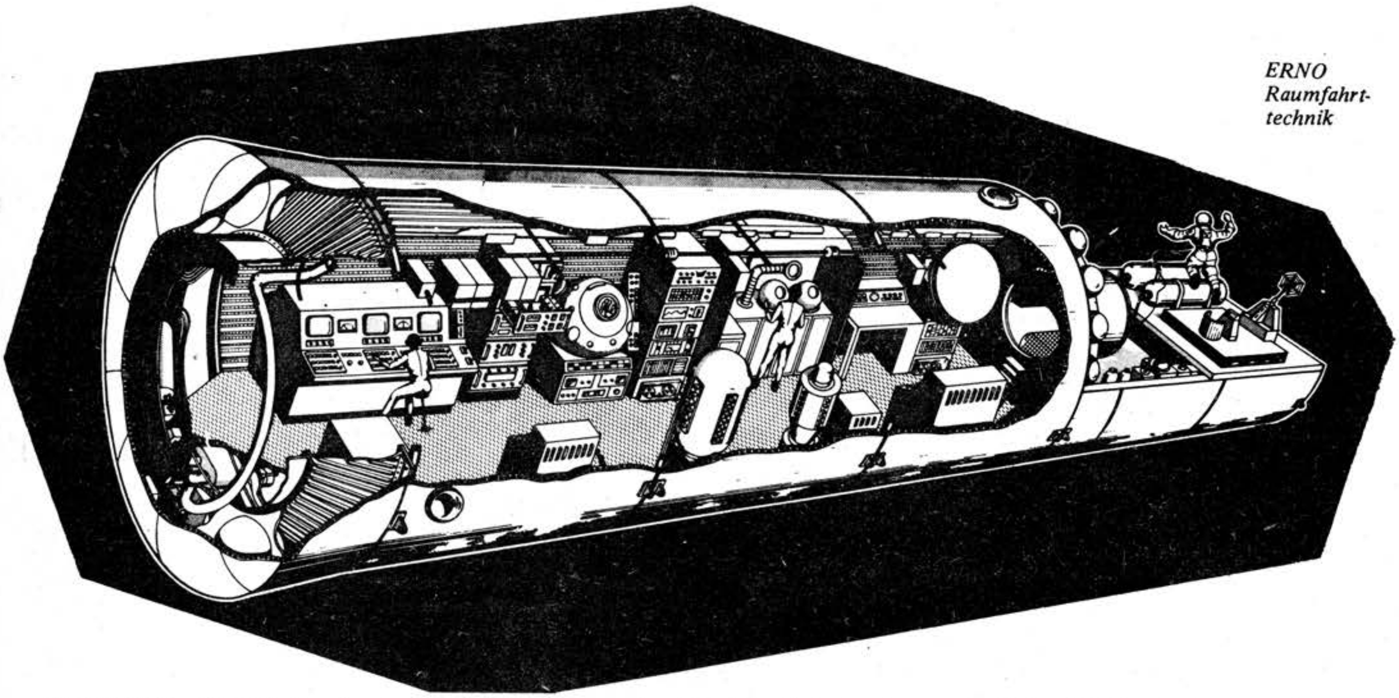
Technical Changes:

So far our analysis has looked at the definitive changes brought about by a detailed inspection of the NR design

Messerschmitt-Bolkow-Blohm



Modular concepts of 'Space Lab' were prepared for ESRO by two European industrial teams. Artist's impression shows the version designed by the consortium headed by Messerschmitt-Bolkow-Blohm which includes BAC (UK), CASA (Spain), ETCA (Belgium), FAIR (Italy), Laben (Italy), MSDS (UK), Normalair Garrett (UK), Philips (Netherlands), Selenia (Italy), SEP (France), Siemens AG (W.Germany), and SNIAS (France, Consultants are General Dynamics and Martin Marietta. An alternative concept by the group headed by ERNO appears overleaf. Europe had until 15 August to accept the project as an independent contribution to the NASA space shuttle programme.



'SPACE LAB' – Europe's biggest and most ambitious space project. This is the design by the team headed by ERNO with the companies Dornier, AEG-Telefunken, Standard-Electric-Lorenz, Aeritalia, Hawker Siddeley Dynamics, Engins MATRA, Thomson CSF, Bell Telephone Manufacturing, SABCA, Fokker-VFW and INTA. The project has wide-ranging applications in the fields of astronomy, physics, Earth observation, communications/navigation, materials research, space manufacturing, biology and medicine.

following award of the contract in July 1972. Between RFP documentation and the October baseline the general configuration had changed in several major points. Before looking at the changes that came out of the additional effort by the Space Division it is appropriate to recap the dimensional characteristics of the design as it existed immediately before the October baseline.

The orbiter had a length of 124.4 ft. with a 79.6 ft. wingspan attached to a 182.3 ft. external propellent tank. The boosters,however, were 150.2 ft. long, considerably shorter than the ultimate baseline design. The total length of this configuration was 206.2 ft.

By the time the Space Division had set up the detailed design schedule the Shuttle had taken upon itself the dimensions discussed in the main section of this article. The Programme Requirements Review, held mid-November, 1972, re-sized the configuration once again.

The orbiter was essentially unchanged, with a new length of 125.8 ft. and a span of 83.9 ft. Height to the extreme tip of the tail is now 56.3 ft. The only major change from the detailed review of the October configuration was in the Orbital Manoeuvre System where the engine thrust of each propulsion unit is raised to 6,000 lb. The external propellent tank has now been slimmed and lengthened, with dimensions of 25.3 ft. and 189.8 ft. respectively. This effectively lowers launch and inert weights to 1.732 million lb. and 82,000 lb. respectively. The solid-propellent boosters are larger, with a length of 191.7 ft. and a diameter of 13.5 ft. Some 1,406,167 lb. of propellent is now carried in each booster providing a 1,638,057 lb launch weight, approximately 12.000 lb. heavier per unit. Each booster provides a nominal sea level thrust of 3.9 million lb. which is some 230,000 lb. lower than the September concept.

The overall dimensions of the Shuttle now presented a length of 214.3 ft. and a span of 83.9 ft.

A major design change was also introduced at this time. After much deliberation it was decided to delete the two solid rocket motors for abort contingencies during the first 30 seconds of flight. This saved some 100,000 lb. of weight and helped to provide a new gross lift-off weight of 5.246 million lb. The new launch thrust was 8.925 million lb. and coupled with the decreased weight slightly lowered the T/W ratio.

After 2½ years of change and modification the Shuttle had arrived at a reasonably stable design configuration. Many changes were still in the offing, but discussion of these is deferred to a later report.

Acknowledgements: Among the many professional groups consulted by the author of this article over several years special mention is made of the outstanding contributions of the Space Division of Rockwell International (formerly North American Rockwell) and the United States Senate.

SPACE LAB

Development of Space Lab as an independent European project was still undecided when the European Space Conference broke up on 12 July (see page 321). NASA had given Europe until 10 August to reach a final decision. Ministers represented were due to meet again in Brussels on 31 July.

SATELLITE DIGEST — 62

A monthly listing of all known artificial satellites and spacecraft, compiled by Geoffrey Falworth. Information is based on that supplied by the Space Department of the Royal Aircraft Establishment, Farnborough, NASA, Satellite News and BIS sources. For information on the derivation of orbital parameters, abbreviations, etc., see July 1972 issue, page 262.

Continued from August issue, page 295.

Name, designation and catalogue number	Launch date, lifetime and descent date	Shape and weight (kg)	Size (m)	Perigee height (km)	Apogee height (km)	Orbital inclination (deg.)	Nodal period (min)	Launch centre, launch vehicle and payload/launch origin
Cosmos 550 1973-11A 6376	1973 Mar 1.53 9.8 days (R) 1973 Mar 11.3	Sphere-cylinder 4000?	5 long? 2.44 dia	206	317	65.42	89.33	Plesetsk USSR/USSR
1973-11C 6384	1973 Mar 1.53 16.52 days 1973 Mar 18.05	Sphere?	2 dia?	202	432	65.44	90.85	Plesetsk USSR/USSR (1)
Cosmos 551 1973-12A 6378	1973 Mar 6.39 13.8 days (R) 1973 Mar 20.2	Sphere-cylinder 4000?	5 long? 2.44 dia	206 173 170	296 317 398	65.00 65.00 65.01	89.52 89.40 90.18	Plesetsk USSR/USSR (2)
1973-12D 6389	1973 Mar 6.39 15.86 days 1973 Mar 22.25	Sphere?	2 dia?	170	376	65.02	89.96	Plesetsk USSR/USSR (3)
1973-13A	1973 Mar 6.5 10^6 years	Cylinder? 350?	1.7 long? 1.4 dia?	32100	39660	10.1	1441.0	ETR LC 13 Atlas Agena D DoD/USAF
1973-14A	1973 Mar 9.88	Cylinder-cone + boom 10250	15.25 long 3.55 dia	156 152	273 270	95.72 95.70	88.82 88.76	WTR SLC 4-East Titan 3D DoD/USAF
Meteor 14 1973-15A	1973 Mar 20.47 500 years	Cylinder + 2 panels + antenna	5 long? 1.5 dia	873	892	81.27	102.64	Plesetsk Vostok USSR/USSR (5)
Cosmos 552 1973-16A 6394	1973 Mar 22.42 11.8 days (R) 1973 Apr 3.2	Sphere-cylinder 4000?	5 long? 2.44 dia	204	312	72.84	89.68	Plesetsk USSR/USSR
1973-16C 6397	1973 Mar 22.42 17.59 days 1973 Apr 9.01	Sphere?	2 dia?	199	310	72.85	89.61	Plesetsk USSR/USSR (6)

Supplementary Notes:

(1) Ejected from 1973-11A during 1973 Mar 10.
(2) Orbital data at 1973 Mar 6.8, Mar 9.9 and Mar 15.3.
(3) Ejected from 1973-12A at 1973 Mar 16.
(4) Orbital data at 1973 Mar 10.16 and Mar 10.7.
(5) 20th operational Soviet meteorological satellite maintains global satellite TV observational capability of Earth's weather, cloud cover, ice and snow fields and thermal emissions from Earth's dayside and nightside surface and atmosphere. Constantly solar-oriented solar cell array panels supply power and gravity gradient stabilisation systems maintain attitude control.
(6) Ejected from 1973-16A at about 1973 Mar 26.

Amendments:

Cosmos 382 (1970-103A) shape is Irregular cylinder + 4 panels + antenna, weight is 18900?, size is 12 long?, 4 dia?
Cosmos 482 (1972-23A) lifetime is 5 years.
Sret 1 (1972-25B) second orbit perigee is 350, apogee is 39358, inclination is 65.6, period is 704.6. Add to Supplementary Note (3): Orbital data at 1972 May 1.0 and Sep 22.0.

SOVIET WEATHER ROCKETS

A series of launchings of Soviet weather rockets has been completed on the French island of Kerguelen in the southern part of the Indian Ocean. There has been an average of two launchings a week since the first of the 20 upper air sounding rockets ascended on 27 February. Altitudes ranged between 71 and 76 km. The experiments were conducted under the Soviet-French agreement for joint research in space meteorology and aeronomy signed in the autumn last year.

The deputy head of the Soviet weather service, Yuri Izrael, said in a press interview that the businesslike co-operation with the French experts and the goodwill displayed were largely responsible for the success of the Soviet expedition.

Izrael noted that it was the first series of regular launchings of weather rockets at 50°S. Upper air sounding was of special interest for Soviet experts. It was essential to have a record of changes in temperatures, atmospheric pressure and wind to be able to make certain types of weather forecasting. Such records supplemented data obtained with probes at lower altitudes.

The Soviet Union has been launching weather rockets for more than 20 years. Until recently four sites were used — Franz-Josef Land, a site near Volgograd, the Thumba range in Southern India and the Molodyozhnaya station in the Antarctic. Kerguelen was a valuable addition to the meridional network for upper atmosphere study.

SPACE REPORT

A regular monthly review of Space Events and Technical Trends

TOWARDS INTELSAT 5

A full-size engineering version of a spacecraft designed to meet the exacting needs of the next generation of communications satellites is being demonstrated at the Lockheed Missiles and Space Company* in Sunnyvale, California. The test-satellite was assembled from components supplied by an international team of 17 companies in 10 countries which includes Marconi Space & Defence Systems.

Tests now underway are proving the feasibility and reliability of the satellite as the team prepares for the Intelsat 5 competition expected to begin early next year.

The enterprise is privately financed by companies in the team and will offer a communications capacity at least five or six times greater than present Intelsat 4 satellites. It is designed to provide a variety of communications services across oceans or large expanses of land.

The added capability will be required during the next 10 to 15 years to keep pace with the rapid growth in international telecommunications. Although growth rates have varied considerably in the past, conservative estimates show that telephone traffic between nations can be expected to increase between 20 and 25% annually during 1975-1985.

To meet growing demand, Lockheed and its international team pooled their resources to design the new generation of communications satellites. Among the missions the new satellite could perform are international or domestic communication, TV distribution, direct broadcast TV, satellite data relay and certain forms of aircraft and ship navigation.

For economic reasons, increased flexibility and long life will be key features required in the next generation of satellites. To achieve flexibility, the Lockheed team used the 'bus' concept in the design. This means that the same basic spacecraft can be adapted for a variety of missions by changing subsystems and minor modifications but without major spacecraft redesign.

By employing this 'bus' concept, traffic pattern changes over the lifetime of the satellite can be accomodated by designing into it a capability to switch transponder channels and to accurately steer the various antennae beams. For long life the satellite is designed with full redundancy – in some cases multiple redundancy – in every critical module and component.

Other major technological improvements are:

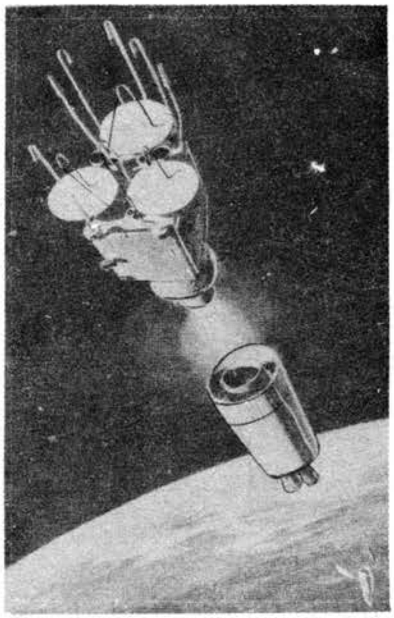
1. Three axis spacecraft stabilisation by internal momentum wheels.
2. Flexible, unfurlable, sun-tracking solar arrays capable of producing from one to five kilowatts of available DC power.
3. Use of 11 and 14 GHz frequency bands as well as 4 and 6 GHz bands.
4. Combination hydrazine thruster/ion engine propulsion for station-keeping.
5. Antennae pointing accuracy of 0.16 degree and station keeping accuracy of plus or minus 0.1 deg. East-West and North-South.
6. One hundred per cent operational capability during eclipse.

Satellite mass can vary from 1,700 to 3,800 lb. depending on the payload. One-third of the total mass is allocated to the communications payload.

While the team venture is important because of the technical advances it has proposed in satellite communications, it is also significant as a successful experiment in international co-operation. All team members share in the responsibility for development and management of the system and all will share in the rewards if they are selected to build the Intelsat 5 communications satellites.

Artist's impression of Intelsat 5 being injected into geo-stationary orbit.

Lockheed Missiles and Space Company



Responsibility breaks down as follows:

Etudes Techniques et Constructions Aerospatiales/Ateliers De Constructions Electriques de Charleroi (ETCA/ACEC), Belgium:	- Charge control, voltage regulator, and low voltage power supply.
Spar Aerospace Products Ltd., Canada:	- solar array structure and mechanisms.
Royal Netherlands Aircraft Factories-Fokker, Amsterdam, The Netherlands:	- spacecraft structural analyses.
Marconi Space & Defence Systems Ltd., England:	- attitude sensors.
Thomson-CSF, France:	- transponders.
Societe Anonyme de Telecommunications, France:	- solar cell and encoders.
Societe des Accumulateurs Fixes et de Traction, France:	- batteries.
Societe Europeenne de Propulsion (SEP), France:	- ion engine and tanks, hydrazine thrusters.
Teldix, GMBH, W. Germany:	- stabilisation wheels.
AERITALIA, Italy:	- adapter, ground handling equipment and booster interstage.
Siemens, Halske A.G., Munchen, W. Germany	- transponder subsystems.
Selenia, S.p.A. Industrie Elettroniche Associate, Italy:	- solar cells, TT&C equipment.
Contraves, A.G., Switzerland.	- spacecraft, structure parts for transponder and battery.
FIAR CGE-Compagnia Generale di Electricita, S. p. A., Italy:	- local oscillators, TWT power supplies.
Mitsubishi Electric Corporation, Japan:	- IF amplifiers UP-converters.
AEG-Telefunken, W. Germany	- solar cells.

Customer: International Telecommunications Satellite Consortium.

Quantity: Up to six in the initial procurement.

Desciption: The proposed new international communications satellite is a 3-axis stabilised spacecraft offering payload capacity and operational capabilities several times greater than existing satellites. Its basic design stems from the experience which produced the Agena spacecraft, the vehicle which has accounted for more than one-half of all payloads the US has placed in orbit. In addition to the flight-proven stabilisation system, the new satellite also will feature a unique modular design which permits payload flexibility and adaptability without changes to the basic spacecraft. It will have large, sun-oriented solar arrays capable of producing five to seven kilowatts of available D.C. power, antenna pointing accuracy of 0.16 degree, orbital station-keeping accuracy of plus or minus 0.1 degree, and an in-orbit life of up to 10 years.

Intelsat 5 : Planned launch dates.

Prototype launch - mid-1977. This will be a pre-operational satellite for system shake-down, test etc.

Operational Launch - mid-1978. For operational communications service.

Satellite dimensions:
Length: 8.66 ft (2.6 metres)
Width: 6.06 ft (1.82 metres)
Depth: 3.16 ft (0.95 metres)

Solar arrays, tip to tip are 48.26 ft. (14.48 metres) long. Unfurlable antennae, 7 ft. diameter.

PETREL AT SOUTH UIST

On 3 April seven Bristol Aerojet Petrel rockets were launched during a 12 hr period from the Royal Artillery rocket range on South Uist in the Outer Hebrides. Each rocket carried a payload constructed at the Science Research Council's Radio and Space Research Station, Slough, with multiple experiments for investigation of the ionisation in the upper atmosphere at altitudes above 60 km (40 miles).

This is the first time that more than three Petrel rockets have been launched in a day. The experimental data will provide a clear demonstration of the development of the D-region of the ionosphere through a day and will be used in conjunction with theoretical work which is in progress at RSRS.

The rockets all reached altitudes of about 140 km (90 miles). The measurements were transmitted to the ground station at South Uist by radio telemetry and recorded on magnetic tapes. Examination of 'quick look data' which has been produced since the flights shows that valuable results were obtained from every flight.

Each payload included the following experiments:

1. Measurements of electron concentration and electron collision frequency from Faraday rotation and differential absorption at three radio frequencies transmitted from the ground to the rocket;

2. Measurements of electron concentration fine structure, using a Langmuir probe;

3. Measurement of the intensity of solar ultra violet radiation at 1216 Å (Lyman alpha) and of the molecular oxygen concentration derived from atmospheric absorption of this radiation;

4. Measurement of solar X-rays (2 to 8 Å);

5. An experiment newly developed in collaboration with the Max Planck Institute at Lindau, West Germany and the University College of Wales, Aberystwyth, to measure the concentration of atomic oxygen in the ionosphere from corrosion of thin silver films;

6. In addition, each payload was instrumented to measure the attitude of the vehicle with respect to the Sun, the slant range of the vehicle from the launch site, instrumentation temperatures and other housekeeping functions.

With the exception of the failure of the nosecone to deploy on the last flight, all facilities (rocket motor performance, telemetry, radar tracking, nosecone release) worked perfectly on every flight, while the experiments also had a very high proportion of success including the prime experiment (No. 1) on the last flight. The campaign was not without difficulties, including postponements due to gale-force winds and an unwanted but spectacular aurora. The operation required closely planned team work using the simple but effective ground equipment at South Uist.

The project scientist, Dr. P. H. G. Dickinson of RSRS, has expressed his appreciation of the support provided by staff of the UK Atomic Energy Authority who included meteorological, telemetry and launcher teams, and by the Army which was responsible for range safety, including surveillance radar on St. Kilda.

The project was made feasible by the fact that the Petrel rocket (7.5 in. in diameter and 9 ft. long, including the payload) has shown itself safe to be launched in near gale-force winds, even from South Uist where the safety standards are exceptionally high.

The rocket was designed for SRC and is made by Bristol Aerojet, Banwell, England.

TOWARDS A EURO-COMSAT

Two large European consortia, one lead by the British Aircraft Corporation and the other by Hawker Siddeley Dynamics, have each been awarded a contract worth more than £600,000 for competing project definition studies for the ESRO Orbital Test Satellite, OTS.

The studies, which will lead to the detailed definition of the OTS and the choice of contractor for the hardware phase at the end of the year, will last some 24 weeks. OTS will prove the design concepts and space-quality for hardware to be used in Europe's first communications satellite, the ECS.

BAC Electronic and Space Systems is acting on behalf of the STAR Consortium, consisting of companies in Switzerland, West Germany, Denmark, Sweden and Italy in addition to the United Kingdom. Hawker Siddeley Dynamics leads the MESH Consortium, which likewise includes companies from five other countries.

OTS, a geostationary satellite, will embody three axis jet stabilisation and high-powered, sun-orientated solar arrays and is scheduled to be launched by a Thor-Delta rocket in 1976. It will measure 2 metres in height and 7.6 metres in overall width and weigh 320 kg.

FILM REVIEWS

By John C. Gilbert, A.F.B.I.S.

Anatomy of Success

COMSAT Corp., 16 min. Colour, 1970.

Although not one of the better 'space films' *Anatomy of Success* is interesting for its record of a commercial communications satellite, INTELSAT II, and the evidence of co-operation between commerce and government.

Animation is used to illustrate the concept of the geostationary orbit, and to trace the steps in the actual launch of INTELSAT. The film of the night launch is both impressive and spectacular. After orbit is achieved, control passes from NASA to COMSAT (the international consortium owning INTELSAT II), and this leads to the inaugural intercontinental telecasts.

It is unfortunate that the script is of poor standard and centres rather repetitively, upon the film's title. This is most pronounced in early mosaic sequences of the satellite design and testing when two earlier failures are reported. Seven years before the spacecraft launch, a faulty weld, resulting in a loose particle, caused a failure of the Delta second stage. Six years previously a human error in the design of the fairing separation mechanism ended in a second abortive attempt. This latter error is presented at some length, and is certainly an excellent example of the ever-present need for the space engineer to be aware of the extreme environment of space. In this case due allowance for vacuum had not been made in the construction of a bracket. Slow-motion of Earthbound tests show this adequately.

While not a 'feature' film, it is suitable as a short 'filler', or possibly as an introduction to a lecture on geostationary satellites.

The Knowledge Bank

NASA, 25 min. Colour, 1972.

This reviewer has no hesitation in thoroughly recommending this film to all audiences. There is a need for films, such as this, that reveal the explorations of the near solar system, while the rich harvest of scientific knowledge is virtually ignored. Both aspects of space flight should progress in unison. This film does a lot to redress the balance.

The familiar scene of Earth-rise over the lunar surface is used to open the film, but this time it is a preface to a step back in time – to 1752 and Franklin's experiments with lightning. The progression to Faraday, on to Edison and the first electric light bulb, and finally culminating in our present acceptance of electricity (nicely illustrated by the vivid technicolour of Broadway lights) is used as an analogy showing the paths of scientific exploration from uncertain investigations to the utilization of natural phenomena for the benefit of Mankind.

A Saturn lift-off opens the setting for space in the 70's. From early balloons, sounding rockets and then the satellite – the ceiling of atmospheric explorations has extended until it encompassed space – and the solar system. From 1957 the satellite era provided ever-increasing scientific returns. The van Allen belts, the magnetosphere and bow-shock, investigations of solar flares – the film spans the range of scientific research satellites and glances tantalizingly at the results. The Orbiting Geophysical Observatory is but one of this collection – and as the film reports, each adds to the 'deposits in the bank of knowledge', whether this be toward a unified pattern of world weather, or study of electric/magnetic phenomena.

For the physicist and astronomer the blanketing by the atmosphere has been removed. OSO's map the Sun, investigate the effects of the solar energy on the Earth's environment, OAO with its variety of UV and X-ray telescopes scans the skies, examine pulsars and quasars, study the radio noise emanating from Jupiter. Lunar orbiting satellites will further our knowledge of the Moon.

All these, and more, are covered in the film, to present a picture of the scientific advances to be gained in space. Justification can be found in Man's need to search even further for knowledge and understanding. In the Universe is visible the past and future.

As with Franklin, the material benefits will come tomorrow.

ERTS – Earth Resources Technology Satellite

NASA, 27 min. Colour, 1973

A happy blend between the factual explanation and pictorial content makes this an enjoyable film that is highly recommended.

Several projects from a number of research centres taking advantage of ERTS were covered, although not exhaustively, the aim being to introduce some different applications for which ERTS is a necessary (even, essential) tool.

The operation of ERTS was described, with an explanation of its coverage of the Earth's surface. Data transmission and storage is an important facet of the mission; while the preparation and distribution of the data is a mammoth operation. It was facinating to see this side of ERTS, which gave some conception of the magnitude of the whole project.

The distribution of data is a primary step. Analysis is an equally large task, and many new tools have been developed for the purpose. Some of these – such as the colour additive viewer – were shown.

The application of the ERTS data to understanding a number of phenomena was exemplified by such studies as urban sprawl, rural development, and geological surveys of remote areas in Alaska. The multi-disciplinary nature of the project was emphasised, with backup field trips to follow-up satellite reconnaissance shown.

It was gratifying to see immediate benefits accruing – a case illustrating this was property definition in South America (where the mean high water level needs to be determined!). One use to follow, i.e. river flow and precipitation, will be a valuable early-warning system for flood protection.

Some of the spectrum of ERTS activity, from agricultural to minery surveys, are covered in the film, which certainly gives part of the answer to the question 'What do *we* get from space?'

Exploration of the Planets

NASA, 25 min. Colour, 1972

The seventies are already under way, but this film uses the achievements of the beginning of this decade to show the path of solar system exploration for the remainder.

The Viking Mars landings in 1975 are one of the highlights to be expected, yet we can hope that, by 1980, all the larger bodies in the solar system will have been viewed at close range, albeit by remote sensors.

This film gives a tantalizing picture of exotic missions – the Pioneer probes to the outer planets and Mariner to fly-by Venus and Mercury.

This film provides a facinating view of what may be achieved, and what it is hoped to achieve, by 1980. It will be interesting to view it again at the end of the seventies to see how much of its optimism is fulfilled.

BOOK REVIEWS

Edited by L. J. Carter, ACIS, FBIS.

'Astronomy'

By Colin A. Ronan, David & Charles, pp. 108, 1973, £3.25.

This book should not be classed with the large number already dealing with Historical Astronomy. Although, by its nature, it must deal with the same source material, the final result is far superior. The author has adopted the unusual technique of selecting passages from the great works of Astronomy and allowing them to speak for themselves, merely adding small linking paragraphs.

Insofar as it is possible to do so, the book is split into five categories, i.e., Solar System, Stars, Nebulae, the Universe and Cosmology, hence avoiding the usual mixed bag of information, but not neglecting the important connections between the subjects. It is lavishly illustrated, with many familiar and some not so familiar illustrations. This, however, is the one source of complaint, for the legends sometimes become confused with the text, and the connection between some of the illustrations and the text is not very obvious. This is particularly noticeable in the last chapter where Figs. 87 and 88 are referred to but the illustrations stop at Fig. 86!

The arguments involved in the extracts are not simple, but this book should have a wide readership from both the professional astronomer and the layman. It is like a book with the joint authorship of Ptolemy, Copernicus, Kepler, Newton, Hoyle, etc.

ANDREW ALLARDYCE

'Observers's Book of Manned Spaceflight'

By R. Turnhill, Warne, pp 191, 1972, 50p.

Have you ever wished that you had all the up-to-date Spaceflight statistics in handy pocket form? Pine no longer, because they are all here in this admirable little book, the latest in the Observer series.

As BBC Air and Defence correspondent, Mr. Turnhill is in an ideal position to gather the fullest information both from US and Soviet sources, and he has edited and presented his material in excellent fashion.

Potted technical accounts are given of all the space vehicles, the launchers, the space centres and the spacemen themselves. The history of manned space missions can be studied chronologically by easy reference to five pages of US and Russian Space Logs. To complement the high quality of the text, a selection of the best colour plates and some interesting black and white photographs are included. However, one wonders what oversight allowed the captioning of Plate 2 as 'The first spacewalk by Ed. White from Gemini IV', or Plate 3 as 'The first rendezvous in space between Geminis VI and VII'. I am glad to say that the text is more explicit. Good line drawings are marred by the simple omission of component labelling, so the space tyro will be ignorant of what he is looking at.

As a potential buyer, I wish that the release of this book had been delayed to include fuller results from Apollo 17. The preflight summary is no substitute, though it reflects the author's confidence in the success of the mission. Projected details of Skylab and the Shuttle are included, but the Apollo/Soyuz linkup only merits a mention in the Introduction. Generally the author has provided us with a very useful 50p worth, and I was pleased to read that a companion volume on unmanned spaceflight is planned.

A. M. NIXON

Exploring Space

By Kenneth W. Gatland, Macdonald/Educational, pp. 48, 1972, 90p.

There is a constant need for books to educate and stimulate the interest of the young. A pre-requisite for this is that such books should have a visual impact to encourage reading the accompanying text. A picture book alone is not enough: it must have text which is both lucid and informative, with explanation of complicated principles achieved with carefully selected illustrations. It is essential that coherence be maintained throughout the volume to ensure the continuing interest of the reader.

This small handy book embodies all these essentials. There is immediate visual impact on every page. Indeed, each pair of facing pages describe just one facet of the primary topic. This has the advantage that there is no distraction due to a glimpse of the following subject. A rigid format such as this might well have the disadvantage of non-uniformity between sections when an attempt is made to cut a detailed subject to fit two pages (or, indeed, to expand a minor one). The author avoids this dilemma by careful selection of the subject. This, together with a relaxed style, enables such diversified topics as radio astronomy, planetary science and space travel to be covered without discontinuity.

Beginning with the dawn of astronomy the reader is taken through the solar system, with studies of Sun and Moon – the latter emphasising the manned exploration of our neighbour-planets, and then via interplanetary space to the galaxy, concluding with a discussion on the nature of the Universe and the next steps in space. A projects section clearly describing the manufacture of a refracting telescope and mount is included. The instructions are clear and the diagrams most helpful for any young person to attempt the construction of a telescope at home. It is hoped that the reader will be inspired to see for himself the wonders of the Universe. At the end of the volume is a reasonably comprehensive index.

The layout is excellent – the choice of illustrations being most commendable. The sections dealing with manned space flight include a description of rocketry and the lunar landing. The lunar roving vehicle (and the Soviet Lunokhod) is described in another section, while the space suits used for manned exploration comprise another. Skylab is included as a separate topic.

It would be easy for the young reader to be fascinated by any section.

This is an ideal gift,even to someone with no special interest in space. The book is specially recommended for the young reader, who should derive hours of pleasure (and acquire some knowledge) from it.

JOHN C. GILBERT

Renzao Diqiuweixing ('Man-Made Satellite')

Shangai Revolutionary Press, 1970, 76 pp. (8p from Guanghwa Bookshop, 9 Newport Street, London, W.C.2.

First published in Shanghai in July 1970, this little book (in Chinese), apparently aimed at Middle School level, is liberally illustrated with very good black and white diagrams. On several pages there are line drawings of a finned three stage rocket, which does not look like an American or Soviet booster, but the accompanying text is very general

PETER RYAN

Reports Available for Loan

Many of the items listed are available on loan through the Society. Requests should be sent to the Executive Secretary enclosing 25p (minimum postage rate) for each book or report desired. Items are forwarded only on the understanding that the maximum loan period of one month will not be exceeded. This must be strictly adhered to, to avoid inconvenience to other borrowers.

HISTORY OF PROJECTS & SPACECRAFT

Author	*Title*	*Year of Publication*
Buedeler, W.	Operation Vanguard	1957
Chapman, J. L.	Atlas	1960
Dornberger, W.	V.2.	1954
Green, C. M, *et al.*	Vanguard: A History	1971
Klec, E, *et al.*	The Birth of the Missile (Peenemunde)	1956
Pocock, R. F.	German Guided Missile of WWII	1967
Riabchikov, E.	Russians in Space	1971
Samson, D.R. (Ed.)	Development of the Blue Streak Satellite Launcher	1963
Shelton, W.	Soviet Space Exploration, the 1st Decade	1969
Simon, L. E.	German Research in WWII	1947
Sobel, L.A. (Ed.)	Space: From Sputnik to Gemini	1965
Southall, T.	Woomera	1962
Stoiko, M.	Soviet Rocketry: The 1st Decade of Achievement	1970
Swenson, L. S, *et al.*	This New Ocean (Project Mercury)	1966
WuKelic, G. E. (Ed.)	Handbook of Soviet Space Science Research	1968
Young, H, *et al.*	Journey to Tranquility (Apollo 11)	1969
Ziegler, M.	Rocket Fighter (Me163) (from 1961 German Edition)	1963

Reports

Number	*Title*	*Year*
SP-151	Relay Programme: Final Report	1968
SP-184	Surveyor: Programme Results	1969
SP-293	Exametnet, The first Five Years 1966-70	1972
SP-4001	Project Mercury – a chronology	1963
SP-4002	Project Gemini – a chronology	1969
SP-4009	The Apollo Spacecraft – a chronology Vol. I. (to Nov. 1962)	1969
SP-4202	Vanguard – a history	1970
SP-155	Significant Achievements in Space Sciences 1966	1967
SP-156	Significant Achievements in Space Applications 1966	1967
SP-4004-8, 4010,4014	Astronautics and Aeronautics 1963-9 respectively	1964 - 70
SP-4401	NASA Sounding Rockets 1958-68: A Historical Summary	1971
NASA BOOK REPORT	Aeronautics and Astronautics 1915-1960	
NASA REPORT	to U.S. House of Representation Astronautical and Aeronautical Events of 1962	
NASA Historical Essay Award.	Development of the Life-saving Rocket, a Study of 19th Century Technological Fall-out	1968

Biographies

Gagarin, Y. (autobiog.)	Road to the Stars	(No date)
Abbas, K. A.	Till we reach the stars (the story of Yuri Gagarin)	1961
Grissom, V. (Gus) (autobiog.)	Gemini	1958
Bloom, U.	He lit the Lamp (biog. of Prof.A. M. Low)	1958
Walters, H. B.	Hermann Oberth, father of Space Travel	1962
Thomas, S.	Men of Space. Vol. 8. (European and International Scientific groups)	1968

SPACE EDUCATION

Books

Chisnall,G.A, *et al.*	Astronomy and Spaceflight	1962
Langton, N.H.(Ed.)	The Space Environment	1969
as above	Rocket Propulsion	1970
Moore, P.	Astronomy for O-Level	1970
Posin, D.Q.	Science in the Space Age	1965

Reports

NASA	Model Spacecraft Construction	1966
NASA	Space Mathematics – A Resource for Teachers	1972
EP-32	Learning about Space Careers	
EP-33	Seven Steps to a Career in Space Science and Technology	
CR-2061	University Role in Astronaut Life Support Systems: Space Power Supply Systems	

SPACE MATERIALS

Books

Espe, W.	Materials of High Vacuum Technology: Vol. 1. Metals and Metalliods	1966
Goetzel, C.G.(Ed.)	Space Materials Handbook	1965
Kennedy A. J.	Materials background to Space Technology	1964
Segal, C. L. (Ed.)	Polymers in Space Research	1970
Timmerhaus,K.D. (Ed.)	Advances in Cryogenic Engineering Vol. 5.	1960

Reports

SP-227	Aerospace Structural Materials	
SP-245	Recent Advances in Refractory Alloys for Space Power Systems	
SP-3051	Space Materials Handbook: 3rd Edition	
SP-3025	as above. Supplement to 2nd Edition	
CR-974	Influence of Structure and Material Research on Advanced Launch Systems' weight, performance and cost	
CR-2045	Evaluation of Insulation Materials and Composites for use in a Nuclear Radiation Environment: Phase I.	
CR-2042	As above: Phase II.	
S.P.I.E.	Vol: 21. Fiber Optics – Applications and Technology.	1970

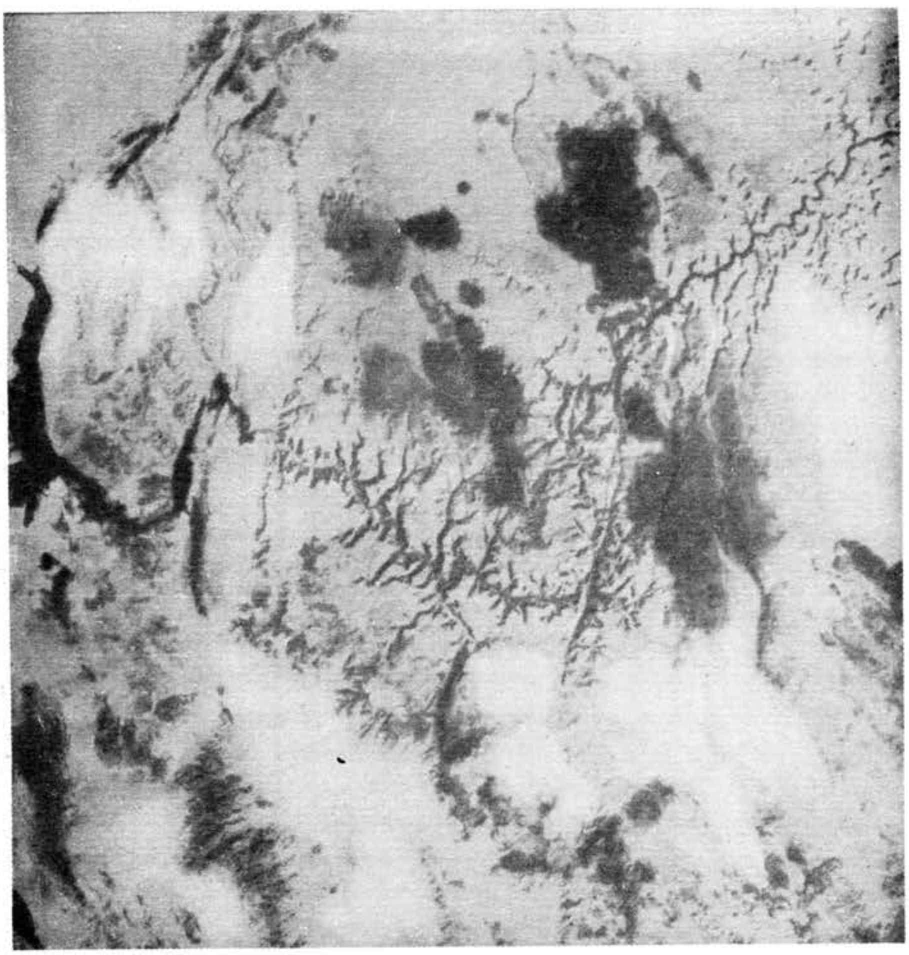
SPACE LAW

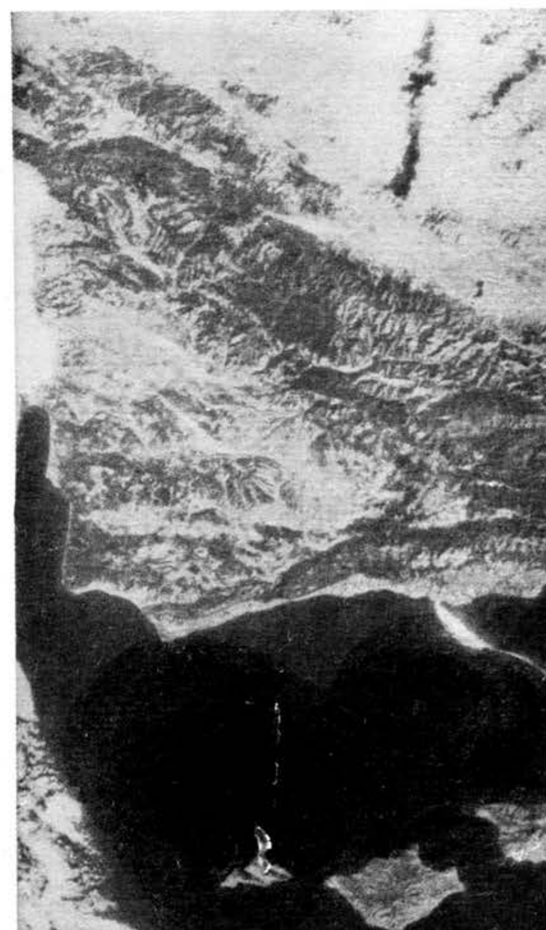
SP-44	Conference on the Law of Space & of Space Communications	

SPACEFLIGHT

88905 КОСМИЧЕСКИЕ ПОЛЕТЫ № Т-10
(спейсфлайт)
По подписке 1973 г.

Volume 15 No. 10 October 1973





Published by The British Interplanetary Socie

SPACEFLIGHT

A Publication of The British Interplanetary Society

Editor:
Kenneth W. Gatland, FRAS, FBIS

Assistant Editor:
L. J. Carter, ACIS, FBIS

VOLUME 15 NO 10 OCTOBER 1973 *Published 15 Sept 1973*

CONTENTS

COVER

GRAND TOUR FROM SPACE. On 23 October the B.I.S. Grand Tour Party leaves Gatwick Airport for a 13-day tour of U.S. West Coast space centres and natural splendours. Pictures from the NASA Earth Technology Satellite trace the route. *Top Left,* Grand Canyon region from an altitude of 914 km (568 miles), far left centre; Shivwits Plateau, centre, Colorado River, upper right; Coconino Plateau, far right centre. It is of interest to compare this with pictures of canyons and 'dry river bed' features on Mars (see *Spaceflight* May 1972, pp. 176-177). *Top right,* region of Santa Barbara, California showing Vandenberg Air Force Base at extreme left, below the islands of Santa Rosa and Santa Cruz. On actual photograph launch pads at Vandenberg are visible. *Bottom,* departure and return, ERTS captures a picture of Southern England and the Isle of Wight.

National Aeronautics and Space Administration

MILESTONES

July

16 NASA's Marshall Space Flight Center invites four companies to submit proposals for solid rocket motors (SRM) for the space shuttle – Aerojet Solid Propulsion Co; Lockheed Propulsion Co; Thiokol Chemical Corp., and United Technology Center. Technical proposals due 27 August; cost proposals 30 August. Each of two 120 ft. long x 12 ft. diameter units will weigh about 1.1 million lb, including 1 million lb propellents, have a maximum thrust of 2.5 million lb and burn for about 125 sec. They will be jettisoned into the ocean for parachute recovery.

20 NASA changes planned mission duration of second manned Skylab mission from 56 to 59 days 'to provide a better recovery posture'. Splashdown now scheduled for 6.26 p.m. EDT 25 September in Pacific 544 km (340 miles) south west of San Diego.

21 Soviets launch Mars 4 spacecraft by Proton rocket from Baikonur cosmodrome at 10.31 p.m. (Moscow time) 'to continue scientific exploration of Mars and surrounding space begun by the automatic interplanetary stations Mars 2 and Mars 3 in 1971'. Will arrive in mid-February 1974.

25 Soviets launch Mars 5 spacecraft by Proton rocket from Baikonur cosmodrome at 9.56 p.m. (Moscow time) with same objectives as Mars 4. Left Earth parking orbit at 11.15 p.m. (Moscow time).

26 Mars 4 and Mars 5 are 1,460,000 km and 66,000 km from Earth respectively.

28 Second Skylab crew launched in Apollo CSM by Saturn IB from Kennedy Space Center at 12.08 BST. Astronauts are Cdr. Alan Bean, 41, Dr. Owen Garriott, 42, and Major Jack Lousma, 37. Craft docks with Skylab after 7½ hours.

August

1 Aerospace Ministers of eleven European countries, at resumed European Space Conference in Brussels, confirm creation of European Space Agency by 1 April 1974, and endorse three major projects: German-backed Space Lab (£128 million); French-backed L-3S launcher (£190 million), and British-backed maritime satellite Marots (£31 million). Italy, Norway and Sweden to decide project support by mid-September.See article pp. 384-5.

1 Skylab astronauts recovering from 'motion sickness' complete first full day of experiments. Spacewalk to fix new sunshield is deferred.

2 Two of four sets of attitude control thrusters on Skylab Apollo ferry reported to be leaking, reducing craft's attitude control system to 'minimum flyable condition'.

3 NASA prepares to convert third Skylab Apollo ferry as 5-seat rescue craft for possible launch on 5 September, manned by ex-test pilot Vance Brand and Dr. Don Lind. Planned spacewalk to fix new sunshield by Skylab crew deferred to 6 August.

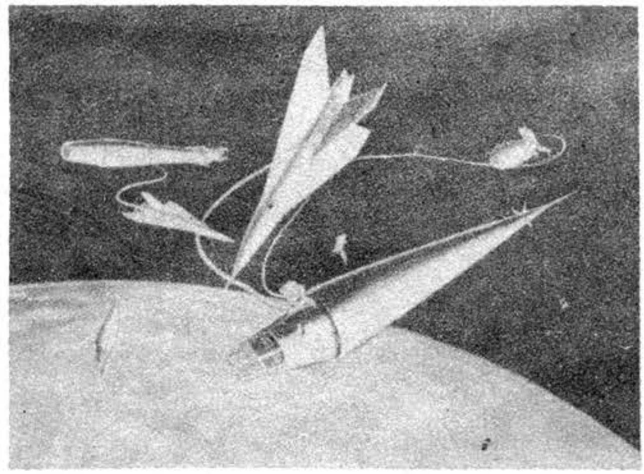
4 NASA announces that Skylab rescue mission may not be necessary but emergency plans continue. If mission reverts to normal, original three-man astronaut team will be launched 9 November.

AFTER APOLLO

By Michael A. G. Michaud

How can Man's enthusiasm for Space be rekindled in the wake of the first manned landings on the Moon? In the coming months we plan to publish a number of articles which postulate new goals in astronautics, including space applications for human need. For example, what impact will regular use of space shuttles have on the management of Earth's natural resources, on materials research and manufacture, and on biology and medicine? We shall look at the possibilities for future major projects in space engineering which could help to solve the 'energy crisis' by tapping solar energy in space. We shall also examine the prospects for 'second-generation', one-stage-to-orbit, shuttles which could make space operations truly economical, bringing such craft into the same flexible regime of reusability as the conventional aeroplane. This first article examines some possible long-range goals in Space Exploration.

Kenneth W. Gatland



Space shuttle re-supply operations in Earth-orbit as envisaged in BIS studies of the early 1950's. In the background, left, is a nuclear powered orbit-to-orbit spaceship being refuelled by a winged orbiter. A shuttle in the foreground takes on propellent from a tanker rocket. At right an astronaut makes use of a 'space taxi'.

Painting by the late R.A. Smith, British Interplanetary Society

Introduction

In December 1972, Americans set foot on the Moon for what may be the last time in this century. When the men of Apollo 17 returned to Earth, they ended a great national adventure which had stirred the world. That adventure had its critics, who saw no purpose beyond the symbolic victory of landing a man on the Moon, of regaining prestige lost with Sputnik.

The war in Viet Nam, other demands for Federal Government money, and growing negativism about spending on technology – all these cut into NASA's budget. Now Apollo is dead, its funding taken away, a skeleton of its team kept together for Skylab and the U.S. – Soviet docking.

A sense of sag pervades the community of interests that supports the space programme. Spaceflight has lost its philosophical drive, and now must be justified on economic, military, or scientific grounds. The emphasis has shifted from space journeys to near Earth systems with a measurable return – satellites, the space shuttle, orbiting modules, the space tug. These will improve our understanding of our own planet, improve communications and navigation, and allow scientific observations which could not be made on Earth. But where does all this lead? If there is a long-term goal, it has not been clearly defined.

Historically, spaceflight has had a philosophical purpose: to carry man to the stars. From early pioneers such as the Russian Tsiolkovsky and the American Goddard to contemporary writers such as Arthur C. Clarke, there was a consistent line of thinking: build the machines that will allow man to escape the confines of Earth and explore the Universe, and expand the realm of the human race. But military exploitation of the rocket and Cold War diverted our thinking, and Project Apollo ultimately left us unsatisfied because it had a short-term goal and did not lead directly to anything else. While Apollo proved that Man could reach another sphere, it did not leave a step to be built upon.

The exploration of space goes on, but by machines and not by men. NASA and the USSR send unmanned probes beyond the near Earth environment to the planets, and into orbits around the Sun. One probe, Pioneer 10, will soon be flung out of the plane of the Solar System, and will be the first man-made object to escape our Sun's gravity. Other probes will orbit the planets and land on those with hard surfaces. This kind of exploration is in the historical mainstream of spaceflight; this is Man expanding into the Universe and discovering how it works.

The unmanned probes could pave the way for man himself, but not unless we develop a coherent set of reasons for a long-term programme of manned space flight. NASA's present finances do not allow it to budget for any manned missions beyond Earth orbit in the remainder of this century. While the Soviets might surprise us, there is no public evidence that they plan long manned space voyages. Once again, Man is confined to the Earth and orbits around it, but this time by a lack of will.

We need to shift gears and return to the main line of development in space flight. We must escape the psychology of the crash programme and the adding machine, and recognize that the purposes of space flight go far beyond our lifetimes. Ultimately, our journey away from Earth will determine the future of the human race; this millennial, evolutionary effort must not founder now for lack of a satistying rationale.

An Ideology of Space Flight

Man is a coincidence. Because conditions on our evolving planet became suitable, simple life began, and gradually evolved and diversified into myriads of ways of existing within the Earth's biosphere, each evolving in response to changes in its environment, some failing to meet the test. Among the survivors is *Homo Sapiens,* the only form of life on this planet that can contemplate where it came from and where it can go.

Until now, humans – and all other Earthly forms of life – have been confined to the thin and fragile biosphere in which they originated. Within these limits, Man's history has been a process of expanding his realm physically and intellectually, reducing the threats to his survival from the environment, and building physical and intellectual tools so that he may grow further. Human philosophical history has

tended to move away from anthropocentrism, reducing Man's assumed place in the order of the Universe. At the same time, Man's power over his physical environment has increased; he is more able to do what he chooses.

Man's discovery of his physical environment has pushed back the limits of his confinement and enticed him to explore further. Always there are people who would hold back, who resist a further step into uncertaintly and another disorienting change in our view of the physical Universe. But, despite delays, Man goes on improving his understanding of where and what he is, and probes the possibilities.

Now, for the first time in the history of life on Earth, one part of it can escape the biosphere of its origin and find or build others. Man has created the option of expanding Earth's living matter throughout the Galaxy. He has opened the door to his closed room, and is looking toward a frontier that may be infinite.

What are human purposes? The purpose of all life forms is survival; on that base we construct others. We can broaden our options for survival, and increase our evolutionary potential. And we can do this in a way that it emotionally and intellectually satisfying.

The tools for the improvement of our survivability are guided evolution, conflict limitation, a balanced relationship to our Earthly environment, and space flight. The first three can improve our chances anywhere that humans live, but are presently limited to the Earth's biosphere. Only space flight can give Man the option of surviving no matter what happens on Earth, of spreading the human race throughout the Universe, of opening up new environments for long-term human evolution.

The Purposes of Space Flight

The basic purpose of space flight is to *expand the realm of Man.* There are several reasons:

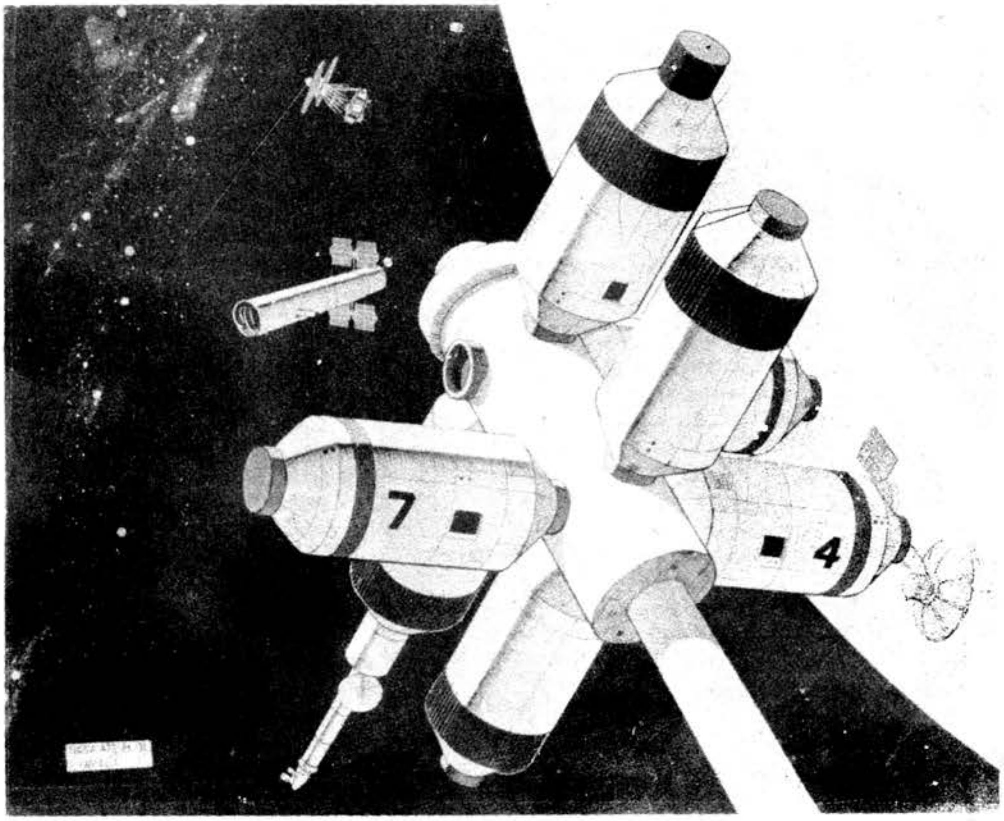
To increase our options for survival. By finding other environments (presumably planetary biospheres) in which humans can survive, we can sharply reduce the risk of the species being eliminated due to an event on the Earth, and can make migration at least possible.

To diversify the human race. Placing humans in new environments will lead to evolutionary adaptations among the colonists. This diversification will enable the species and its descendant species to survive, and to explore new potentials for Man.

To spread human culture. The accumulated knowledge and philosophies of Man can be taken to all our new environments, there to be used and modified by experience. The interaction among human communities and the feedback from their varied experiences will enrich our culture. Our civilization, as well as the human race itself, will be more likely to survive.

To pre-empt confinement. By expanding our realm, we will reduce the likelihood of other intelligent species occupying the habitable planets near us and leaving us with no place to go.

A second reason for space flight is to *challenge human abilities.*



Modular space station as envisaged by the National Aeronautics and Space Administration in 1971. Near the station at left is the Large Astronomical Telescope and at top a Nimbus weather satellite.

National Aeronautics and Space Administration

The challenges of space flight will demand the best from the most talented people, will stimulate human intellectual and organizational abilities, and will force us to develop new concepts, techniques, methods, and materials, some with useful and sometimes unforseen applications in other fields. The people in the space programme will be a cutting edge of the human race, and their work and findings will affect others around them.The explorers themselves will be tested like few humans before them, particularly as distances and travel times lengthen.

Space is the final frontier. It is the ultimate psychological safety valve for a crowded, tension-filled Earth. Like all frontiers, it will attract both the best and the worst in human society, the most energetic along with the misfits, and it will eliminate the weakest. The new frontiersmen will have an impact on the thinking, styles, values, and politics of Earth. They will be affected by new evolutionary pressures that will make them different and perhaps more dynamic and able than their Earth-bound brothers, and better qualified to lead the human race.

A third reason for space flight is to *learn more about the Universe* we live in.

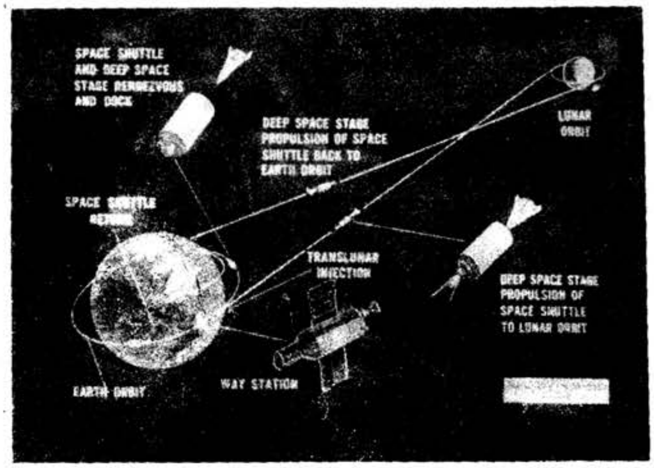
The physical act of exporation, whether it is direct or by sensors, will reveal a new range of physical phenomena that will add to and alter our conception of the Universe. Just in the past decade, we have found spectacular and mysterious sources of energy that no one had expected; manned observatories in Earth orbit or on the Moon will find much more now hidden from us by our atmosphere. By actually travelling to remote bodies, we can test theories more directly, as in exobiology or matter in extreme and unfamiliar states.

So far our direct physical testing of the physical world has been limited to the Earth, the Moon, and meteorites – a limited range of samples. By examining other systems, we will see a wider range of matter and energy conditions, and obtain a broader and surer base for the assertion and testing of physical laws. Our findings will have more universal validity and will illuminate our own system by comparison, e.g., the study of the atmospheres of Venus and Mars may tell us much about our own. The interaction and feedback from these comparative experiences will produce a new physics and a new basis for all our science.

A fourth reason for space flight is to *search for extraterrestrial intelligence and prepare for contact with it.*

Recent discoveries in astronomy and the evolution of life on Earth suggest that life is probably a common phenomenon in many parts of this Galaxy and others, and that we are unlikely to be the only intelligent beings.Sooner or later we are likely to find another civilization, probably by detecting its signals, but possibly by encountering its starships or finding its artifacts on worlds we explore. It would be better for us to search for and find them before they find us, so that we can keep the initiative in deciding if, when, and how contact will take place. Finding other civilizations could have a great impact on our own, if only because it would mean we are not unique and alone. Other intelligent beings may have much to teach us about the survival and adaptation of life in the Universe, and human culture could be greatly enriched by the exchange of information.

Spaceflight and colonization will give us a broader range of experience and capabilities on which to base our approach to advanced extraterrestrials. We will be spread over a large number of planets and solar systems, reducing the possibility of elimination should a conflict occur. Developing our space-



Space Shuttle: Operation between Earth orbit and Lunar Orbit. From a paper by Dr. George E. Mueller, 1968.

National Aeronautics and Space Administration

faring capability and the corollary science and technology will make it increasingly likely that we can deal with advanced extraterrestrials on a basis approaching equality, instead of being fearful, evasive, or even servile.

Exploration of other environments also will tell us much about how life evolves and survives, and about the likelihood of extraterrestrial intelligence, and the means by which we can detect it.

A fifth reason for space flight is to *develop and test technologies for use on Earth.*

The advanced technologies which space travel requires and the new testing environments available in space will produce results usable on Earth. Already we have seen the impact of miniaturization, advanced communication and data processing systems, and special materials used in our first spaceflights. Interplanetary and interstellar travel and communication will require and produce even more dramatic technological advances with 'spinoff' benefits for the Earth.

A sixth reason is to *improve orbital applications of space technology which have direct and immediate benefits.*

A continuing, broad-based space programme will maintain the research, development, and operational capabilities needed for improved satellite systems that study the Earth's climate, resources, and ecology, and make communications and navigation more efficient and reliable. Better military reconnaissance satellites will help to keep the peace. Near future space systems such as the shuttle and the tug will reduce the cost of orbital applications, and orbiting laboratories may begin space manufacturing of very pure medicines, chemicals, and other materials. The feedback from interplanetary flight will improve many of these systems.

A seventh reason is to *stimulate and employ advanced sectors of the economy.*

Space flight will provide challenging employment to the most advanced sectors of the economy that no other civilian programme can match. It will maintain teams of highly imaginative and skilled persons, and will encourage high quality scientific and technological education. It will ensure that research continues in some of the most difficult areas of

science and engineering.

An eighth reason is to *develop and test military technology.* As long as nation-states exist, rivalry and insecurity among them will encourage continuing efforts to improve military technology, particularly deterrent weapons and intelligence collection devices. Space flight is one way in which some of this technology can be developed while accomplishing other purposes at the same time (for example, large boosters and remote sensors).

A ninth reason is to *encourage international co-operation.* Manned interplanetary and interstellar flight would be a major effort for one country acting alone, and separate national space programmes tend to duplicate each other. Collaboration among advanced countries could spread the burden and bring a greater variety of skills to bear, and could encourage peoples to work together on a long-term project in the interest of the human race. In the longer term, contact with extraterrestrials would demand international agreement as to what we would do and say, and possibly an international authority to supervise.

Space Flight: A Programme To Reach The Stars

To motivate a long-term programme of space flight, we need a long-range goal. Interplanetary flight provides a series of goals reachable within human lifetimes; humans may land on another planet in our Solar System before the end of this century. However, these goals will be exhausted before long and interest may wane. We need to set a goal beyond the Moon and the planets.

The goal for *Homo Sapiens* must be interstellar flight. Unlike interplanetary flight, interstellar flight is openended; its frontier is infinite. There is no end to Man's journey to the stars.

Interplanetary flight is a logical and perhaps necessary step to develop the technology, methods, and infra-structure for interstellar flight. But it must not become an end in itself, as Apollo did. The basic thrust of the space programme in the long run must be to carry Man and his instruments to the stars and their planets, primarily to search for new homes for the human race.

For the United States, a symbolic time is approaching: the nation's 200th birthday, in 1976. The bicentennial, coming a year after the US – Soviet docking, would be a suitable time to declare that our goal is to reach the stars.

Preparing for interstellar flight should not stop us from carrying out the most useful missions already planned, such as orbital applications of space technology. Orbital astronomy may become a crucial tool for studying the planets and the stars, and unmanned probes to the planets in this Solar System will be far cheaper, less complicated, and less dangerous than manned probes. Among other things, these tools can determine the feasibility and desirability of manned visits to the planets, especially Mars. The Viking lander in 1976 will be a landmark in this exploration.

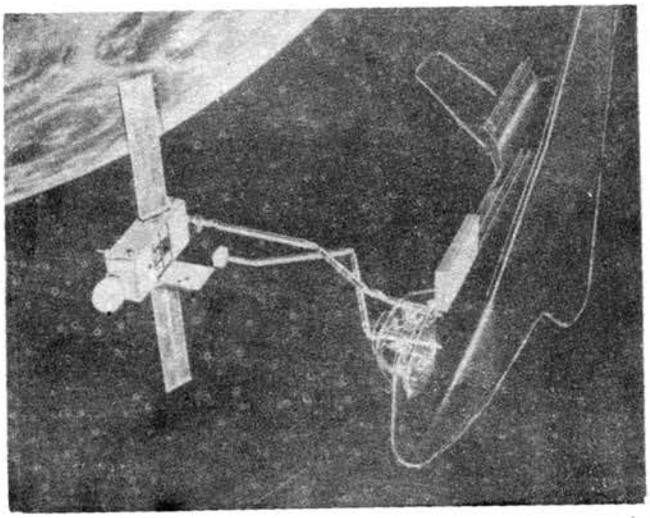
The Medium-Term Programme: To the Year 2000

Assemble a manned space station in Earth orbit. After 1979, the space shuttle will be available to carry modules into orbit which can be assembled into a space station. Besides conducting observations of Earth and astronomical bodies, experimenting in a zero-gravity vacuum, and testing human adaptability to space, the station can be a platform for the construction of manned interplanetary and interstellar ships, drastically reducing the power needed to escape Earth's gravity. This project should be announced by 1976 and completed before 1985.

Build a base on the Moon. Later shuttles will allow us to supply a Moon base where men can study the Universe without atmospheric interference, and can construct instruments too large to operate in Earth orbit. The base also will allow more thorough exploration of the Moon, and will test the logistics and technology for bases on planets. This project could be completed between 1990 and 1995.

Land humans on Mars by the year 2000. Mars is the next step beyond the Moon for manned space flight. Despite its aridity and thin atmosphere, it is the most hospitable environment for Man in this Solar System, other than the Earth. By landing on Mars, remaining for some time, and exploring the Martian environment, men can test the methods that will find new homes for *Homo Sapiens.* The Mars landing will require more advanced spacecraft and life support systems and longer human survival times in space, and will speed the development of interstellar vehicles. The Mars landing is no idle dream; design studies have been done, and the costs estimated. This goal should be declared in 1976.

Prepare for interstellar flight. While manned interstellar flight may be generations away, the initial work should begin now. No later than 1976, a programme should be launched to create the organizational and theoretical framework for the project, outline the work to be done, and begin to mobilize those persons and groups most likely to provide long-term interest and support. A larger, technology-oriented programme should begin by 1980, concentrating first on unmanned probes and later on manned vehicles. The ships and their propulsion systems must be designed, new biological support systems must be developed, and a new communications system planned.



How a space shuttle could be used to replace an equipment module in a malfunctioning satellite using remote-controlled manipulators.

Lockheed Missiles & Space Company

The greatest problems will be achieving near light velocity (186,000 miles a second) to shorten travel time, and maintaining human life aboard a spaceship for a period of years. Research on the ground and feedback from interplanetary vehicles can speed the process of building interstellar probes, and that experience in turn will hasten the time of the manned starship.

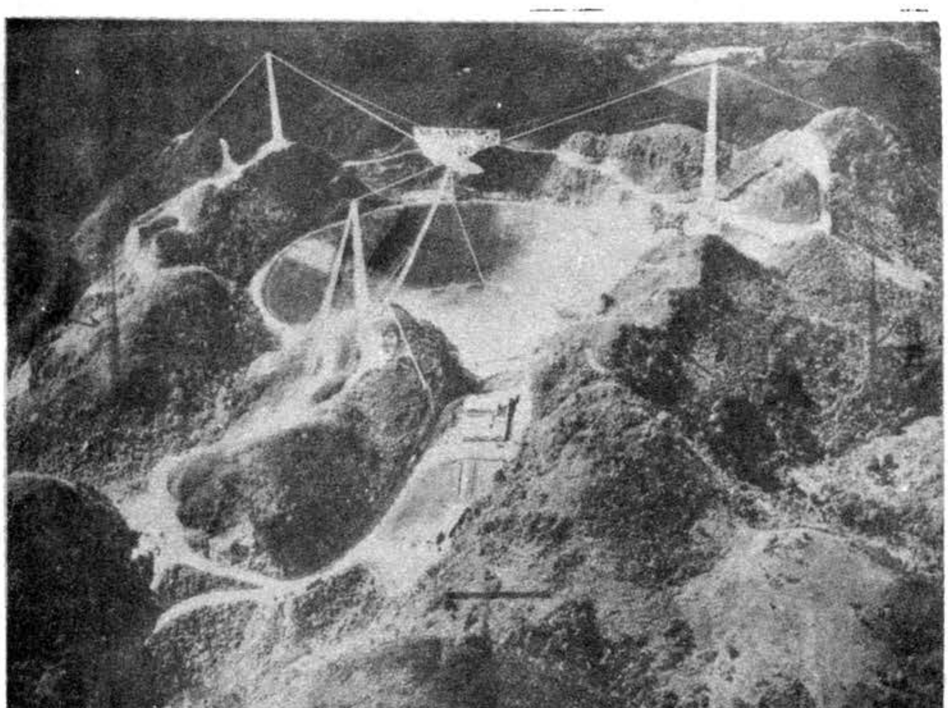
Search for planets in other systems. Increasingly sophisticated astronomical methods have detected large planet-like bodies around nearby stars, and we will find more as our technology improves. Further studies of stellar and planetary evolution will narrow the choices among stars likely to have habitable planets. This search will require the further development of astronomical instruments such as the Very Large Array of radio telescopes being built in New Mexico, and more observing time on existing instruments. The evidence we have already suggests that planets may be surprisingly common.

Begin the search for extraterrestrial intelligence. We have the means now to search for electromagnetic radiation from possible civilizations on planets orbiting nearby stars. This search began tentatively in 1960 with Project Ozma, using the 85 ft. radio telescope at Green Bank, West Virginia, and could be resumed with far more powerful and sophisticated equipment such as the 1,000 ft. radio telescope atArecibo in Puerto Rico, now being resurfaced. The search could tell us much about the frequency as well as the location of other intelligent life, an important factor in our future plans for expansion and colonization. It also could give us the option of communicating with other intelligences in a planned way instead of encountering them accidentally. Finding an extraterrestrial civilization would be the greatest possible stimulus for interstellar flight; thus the search should be a parallel effort with the development of space flight. An initial programme aimed at the nearest stars – and requiring no major new installations – should begin by 1976. All concerned should recognize that the search will be a long-term effort, requiring perhaps decades before finding evidence of extraterrestrial intelligence.

The Long-Term Programme: Beyond 2000

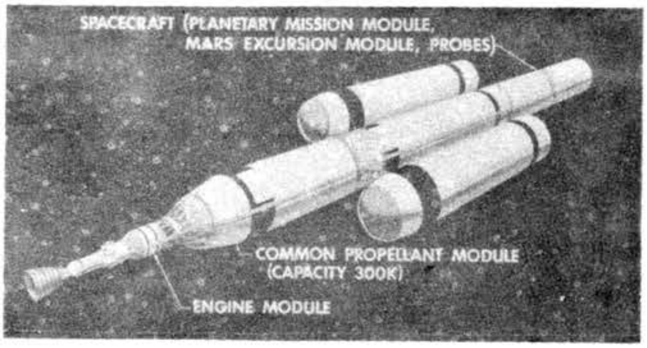
Send unmanned probes to the most promising nearby stars. As in planetary exploration in our own Solar System, unmanned probes should go first to study planets of interest. The probes must achieve extremely high velocities to reach the nearest promising stars within useful times, and must have powerful transmitters to send back the findings of their sensors. The probes will have to be operated by advanced on-board computers that can think for themselves, as they will be too far away for radio instructions from Earth to be timely. By definition, this will be a long-term effort; the infrastructure on Earth must remain in place until the signals from the probes are received, a minimum of several years for the nearest stars. While it is difficult to predict when we will develop a suitable propulsion system, since this may require new discoveries in physics, a tentative date for the launching of the first interstellar probe might be 2010. A possible target would be the α Centauri system, 4.3 light years away.

Create a permanent human colony on Mars. Man's first experiment in living in another planetary environment may be on Mars. If he can adapt by protecting and equipping himself, he will prove his ability to survive in less



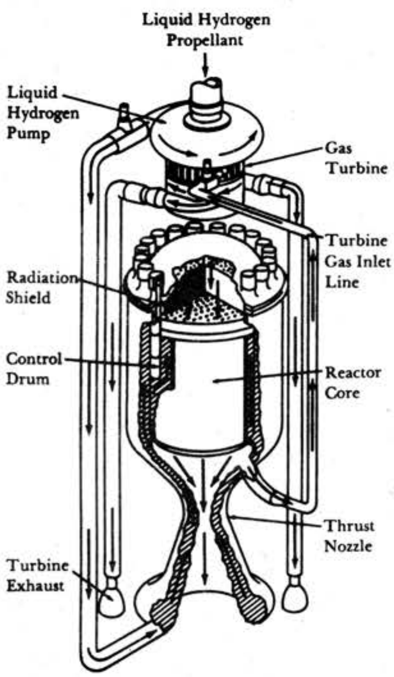
The giant radio telescope at Arecibo, Puerto Rico. The reflector consists of a gigantic cup-shaped steel net 300 metres in diameter set in a natural bowl formed by mountain peaks.

United States Information Service



Above, How NASA envisaged the construction of a manned spaceship for the exploration of Mars.
Below, Nerva nuclear rocket engines (now abandoned) depended on liquid hydrogen being preheated by cooling the thrust nozzle and other components, and then passing through the reactor core to be heated and expanded out through the nozzle. Some hot gas was bled off to power a turbopump that delivered hydrogen to the engine.

National Aeronautics and Space Administration/Westinghouse



difficult biospheres. The raw materials that humans need, such as water and oxygen, are present on Mars, though not convenient; initially the colony would require regular support from Earth. A tentative date for establishing a permanent Mars colony would be 2020.

Planetary engineering. Mars and Venus both have atmospheres, though one is too cold and thin for unprotected humans and the other too hot and thick, and both are dominated by carbon dioxide. Colonists on Mars may be able to gradually change the Martian climate to make the surface more livable, particularly by getting water ice into more useful and accessible forms and by increasing the concentration of oxygen. The first major experiment in planetary engineering may be Venus, where orbiting space vehicles could introduce materials into the atmosphere that might change its composition. This could lead to a reconsideration of Venus as a potential human habitat, though its slow rotation rate and high surface temperature still might make it unlivable for unprotected humans. The lessons of such planetary engineering could be applied on Earth to improve our own climate, and perhaps later to planets in other systems. We may begin modifying the Martian and Venusian atmospheres some time after 2020, and may achieve large-scale improvement before 2100.

Launch the first manned interstellar flights. When the unmanned interstellar probes find a planet suitable for Man, the first manned starship should be readied for its journey. This will require crossing some new scientific and technological frontiers, and will make large-scale interstellar flight seem much more feasible than we can imagine now. Since the launching of the first flight also will have to await radio results from unmanned probes, it is unlikely to take place before 2050 at the earliest. Voyages to nearby systems might be round trips, but longer voyages may have to be one-way attempts to plant permanent colonies because of the passage of years required. We may be planting our first colonies in other solar systems between 2100 and 2150, depending on how far away the systems with hospitable planets are.

Communicate with extraterrestrial intelligence. As Man expands through the nearby section of the Galaxy, the probability of an encounter with advanced extraterrestrials will increase. A search out to hundreds of light years may be necessary to avoid infringing on the territory of another civilization. This may require a great array of radio telescopes similar to that proposed in Project Cyclops. Designers of such an array may learn much during the search for planets. While it is difficult to predict when we will detect signals, it would seem prudent to not reply until we have the capability for interstellar flight. This suggests that our first signals to extraterrestrials would be sent after 2050. Depending on the distance involved, an exchange might require centuries.

The Political Dimension

None of these things will be possible unless continuing, long-term support is mobilized in participating countries. Even if funding for major new projects seems unlikely now, interest must be kept alive. Industrial, labour, military, and scientific interests will continue to be important for the future of space flight, but farsighted political leaders also must mobilize public support with the excitement of exploration and discovery, of expansion and new opportunities, of the change in Man's place in the Universe. They must hold out the promise of new and better lives, not just for a few astronauts, but for ordinary people.

The post-Apollo letdown must not become a political assumption. Whole generations of people have been excited by the promise of space, and have seen what humans did in the twelve short years between Sputnik 1 and Apollo 11. The public mood will change, and that moment must be seized, so that Man can grow, and unlock his fate from the cycles of Earth. 1976 may be the time.

The paper reflects the personal views of the author and does not necessarily indicate U.S. Government policy.

CHILDREN OF THE DAWN

PART 1: THE CASE FOR ASTEROIDAL MISSIONS

By A. D. Farmer

Introduction

Over the past few years there has been a resurgence of interest in the comets and asteroids. In particular, in the USA, NASA has had committees [1] looking into the feasibility of sending space probes to these bodies. We will look below at what is known ot the asteroids and their place in our overall picture of the solar system. Ref. [2] gives a similar synopsis for comets. A second article will look at the types of missions, the vehicles and the observational methods contemplated for asteroidal and cometary visits.

The Why

The region between Mars and Jupiter has been the subject of controversy ever since the Titus-Bode Law (1772) indicated the possibility of a planet missing in this region. This law, empirically based, gave a mathematical series which seemed to govern the distances from the Sun of the planets known at the time: $r = 0.4 + 0.075 \times 2^n$ AU. There appeared to be no planet corresponding to $n = 5$.

It was a fortuitous accident, however, that the first asteroid, Ceres, was discovered by Piazzi in January 1801. The space appeared to be filled. Then in March 1802 Olbers in Bremen found Pallas, and Juno and Vesta followed in 1804 and 1807. The next, Astraea, was not found until 1845 but since then there has not been a single year without at least one new discovery [3]. By 1962 the orbits of 1700 bodies has been accurately determined and many thousands of others had been seen once and lost. Since 1962 many others have joined the list.

Originally, every asteroid was numbered and given a female name; the latter custom has lapsed. Now, upon discovery each asteroid is given a preliminary designation as explained in Table 1. The collation of observations, measurements, etc., has been rationalised to stop wasteful duplication, with major world centres at Leningrad University and the Minor Planets Center, Cincinatti, USA.

Although the number of observations has been enormous, our knowledge still has significant gaps, and very nearly the first question asked after the asteroids' discovery remains a point of fierce argument: whence came this multiplicity of fragments? The two main opposing theories are those of 'fragmentation' and 'accretion'. Like many branches of science, where two apparently opposite (and mutually exclusive) theories are pitted against each other for many years, the real answer may be a combination of each. The theories are outlined below after a review of our present knowledge.

One point stands out about the position the asteroids occupy. They stand at the gateway between the dense terrestial planets and the giant hydrogen balls of the outer regions. This leads to the question; is the multiplicity the result of trying to occupy this region, or is it by chance that the belt is there?

Classical Measurements: The asteroids rarely have diameters greater than tens of kilometres. Most are smaller even than this. This fact, and their generally low albedos, make them dim objects for ground-based observations. At closest approach the brightest (Vesta) is of visual magnitude m_v = 6.5, and most are dimmer than m_v = 8.0.

Few are big enough to give a measurable disc, and those that are, are of sizes so near the diffraction limits of even the largest telescopes that the results are arguable. Measurements by Barnard in 1894-5 at the Lick and Yerkes Observatories using a filar micrometer gave the diameters for Ceres, Pallas, Vesta and Juno shown in Table 1. When considering these results it must be realised that even modern measurements are accurate only to 0.2-0.5″, which is the same order of size as the quoted discs. Several other techniques to measure disc sizes are now available. Most have not been used for the asteroids, but those that have, have merely increasedthe uncertainty. An example is the series of double-image micrometer measurements made by Dolffus; these seemed to confirm Barnard's value for Vesta, but doubled that for Pallas. Infra-red determinations also seem to be in disagreement. Optical measurements have given a value of the major dimension of Eros (it is believed to be triaxial), based on observations during the 1931 close approach (Table 1).

TABLE 1. Determined Body Values for some Asteroids.

Asteroid	Diameter (km)	(Sec)	Mass	Density G/CO	Albedo
1 CERES	770 (Barnard) 1160±80 (IR/Allen)	0.6	$6.0\times10^{-10} M_{Sun}$ (Schubart)	5.5 1.6±0.7	13%
2 PALLAS	490 (Barnard) 950 (Dolffus)	0.6 1.1	$1.5\times10^{-10} M_{Sun}$?	4.6? 0.6?	11%
4 VESTA	390 (Barnard) 390 (Dolffus) 570±10 (IR/Allen)	0.4	$1.2\times10^{-10} M_{Sun}$ (Hertz)	8.5 8.5 2.5±0.7	45%
3 JUNO	195 (Barnard) 290±20 (IR/Allen)	0.2			27%
433 EROS	35 (1931) (35x16x7 from light curve)	0.18			

Designation for new discoveries: year, letter for half-month, letter for which one in that half-month e.g., 1925FA 1st asteroid found 2nd half March 1925.

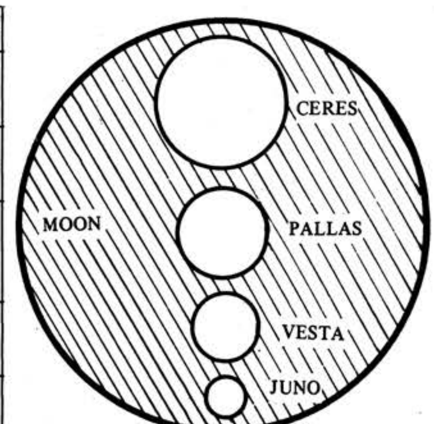


Fig. 1. Approximate sizes of the asteroids Ceres, Pallas, Vesta and Juno, compared to our Moon (based on Barnard's data).

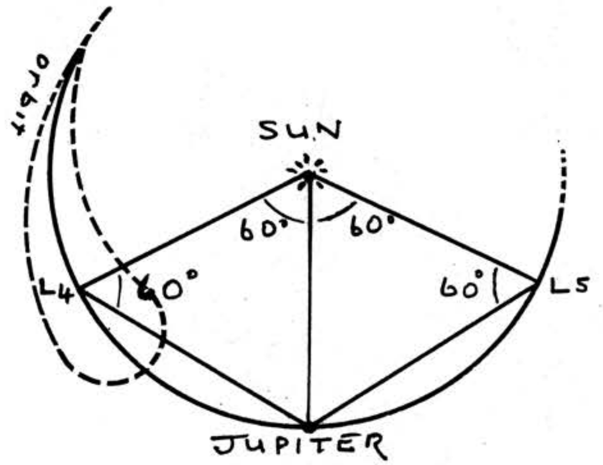


Fig. 2. L4 and L5 are the Trojan points – two of the Lagrangians of the Sun/Jupiter system. Many bodies 'orbit' these in tear drop paths as shown.

The determination of masses has benefitted from recent techniques, starting with Hertz's calculations for Vesta. These were based on its perturbative effect on Arete, another asteroid which approaches Vesta closely and has an orbit commensurable (4:5) with it. This commensurability means that the small gravitational effect is additive over many orbits, and so become measurable. The accuracy of this technique is given tentatively as 10% for Vesta, and it has been extended by Schubart and others (Ref.A) to Ceres, via Ceres-Pallas and Ceres-Vesta interactions. There is a possible bias in the observations on which these Ceres results are based, but this method holds out much promise for the future.

Given mass and diameter, the density is known. The accuracy of this cannot, of course, be better than either of its constituent parts. This is important, as many of the theories concerning the asteroid belt depend on an extrapolation of density from the larger, measured bodies. Further inaccuracies are introduced if the larger bodies are found not to be typical, which is likely. Similar comments hold concerning the derivation of albedoes, and for the estimates of sizes of the smaller bodies by extrapolation of brightness v size data from the larger.

Recent Measurements: Recent work can be divided into statistical and physical studies. Although several of the techniques mentioned have been in use since soon after the discovery of the asteroids, they have been included as 'recent' because it is the development of new skills which has brought these most to fruition.

(a) Statistical: The McDonald Sky Survey and the Palomar-Leiden Survey (PLS) were the two most important examples of attempts to systematically search large enough portions of the sky to give significant statistics for asteroid distribution. There is still a great deal to be settled, however, on the question of possible observational bias in these, and any derived results must therefore be treated with caution.

The PLS gave the total number of asteroids brighter than B(a,0)=21.2 as $4.8(\pm0.3)\times10^5$ [B(a,0) is the brightness of the body at a fixed distance from Earth, and at zero phase angle]. B(a,0)=21.2 is equivalent to a body of about 1.6 km diameter.

The distribution with size shows a discontinuity at about 20 km diameter. This may be significant in deciding between theories of asteroid origin (see below). The number distribution at the lower brightness end is still subject to argument. From the PLS it has been argued that the mass of the whole asteroid belt is about 2x(mass of Ceres), or 2.4×10^{24}g. Other surveys, however, indicate a large increase in the numbers of bodies at larger m_V (as Kuiper suggested, based on the McDonald Sky Survey) and if this is the case the total mass may be several times the PLS result. There have been several suggestions that the belt's total mass could be found from its perturbing effect on other bodies, but so far there have been no useful results.

Other statistical studies have tried to separate the minor planets into groups with similar orbital characteristics. They have long been divided roughly into 'groups' like the Trojans (Fig. 2) at the Jupiter-Sun Lagrangian points, the Apollo types which cross the orbit of Mars, and the Amor types which cross even that of Earth. A few, like Hidalgo, of the 'Saturnian'

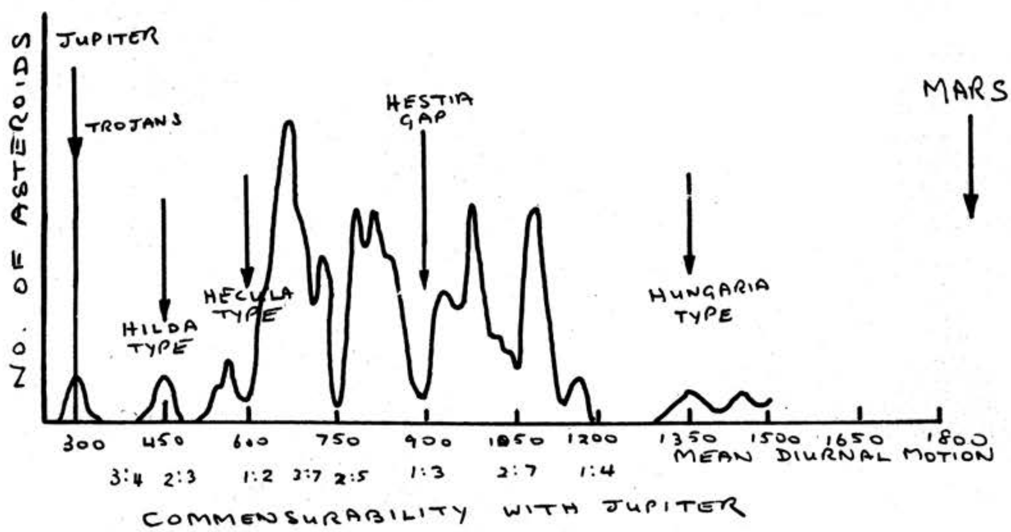


Fig. 3. Distribution of asteroids with mean diurnal motion.

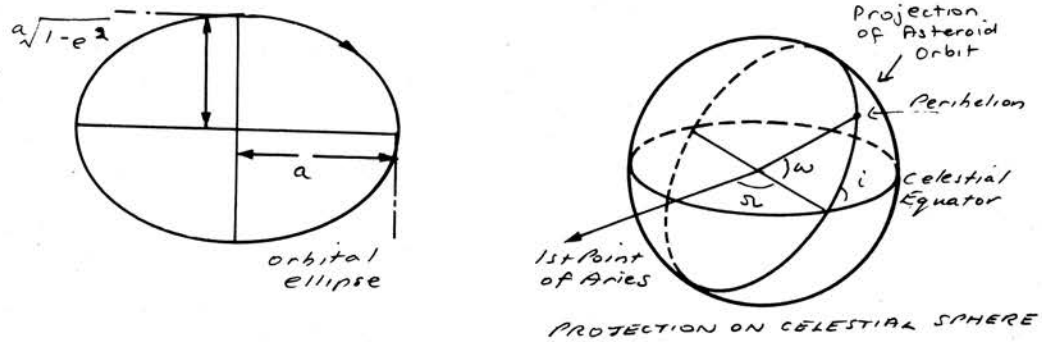


Fig. 4. The orbital elements.

group, go beyond Jupiter, but none (at least down to $m_V = 20.5$) appear to spend their entire lives there. There are, anyway, theoretical reasons for believing this to be an unstable position (see, e.g. Rabe 1972, inc. in Ref.A). No asteroids have been detected beyond Saturn, or at the Saturnian 'Trojan' points.

The orbits of the asteroids, then, lie in the range of periods of 2-6 years. A graph of the number of asteroids in each mean diurnal motion range shows further grouping (Fig. 3). The influence of Jupiter is obvious, with peaks around certain commensurabilities (Hungaria type 2:9, Hilda 2:3, Thule 3:4) and the Kirkwood gaps at others (e.g. Hecula and Hestia gaps). There is also a peaking of the number v. longitude of perihelion at 13.5°, that of Jupiter. If the space distribution is plotted out another effect is seen; there is a sharp cut off of the inner edge at the orbit of Mars. This would indicate that the minor planets were originally spread right across this region, but that Mars has 'swept up' those of the inner edge.

The 'Hirayama' families, defined as groupings in a, i, e space (where these are orbital elements, see Fig. 4), were meant to demonstrate that their constituents were the break-up products of larger bodies. Further orbital elements were introduced in the concept of Brouwer groups, and in the latest, 5-dimensional analysis (a, e, i, ω, Ω) of Alfvén, who has attempted to show that the asteroids 'stream' in groups (see below). The latter work may be a good example of the dangers of bias in observations (here the PLS), as Krésak has shown that all but one of the 'streams' that Alfvén identifies could be artifacts.

(b) Physical: Over the last decade or two several observational techniques have been refined to a highly sophisticated state, and work continues on trying to improve them further:

Infra-red measurements have been mentioned above in connection with diameter determinations. The theory of this is based on each asteroid having reached a radiation balance with solar energy input. The infra-red flux from any body depends on its temperature and its diameter; knowing the first determines the latter. The temperature is set by the incoming (solar) radiation. the albedo, surface characteristics etc. With certain assumptions, therefore, the diameter can be found to the accuracy permitted by those assumptions. Too many unknowns at present make this technique fairly inaccurate, but if other observations could give independent values of diameter, then the infra-red data would give considerable information on the surfaces and shapes.

Infra-red and optical phase measurements (see below) made simultaneously could help determine surfaces of 'spotted' light and dark patterns from irregular ones.

Optical techniques of several types are now in use. Spectrophotometry measures the intensity of light from the body in different colour ranges. The older method of doing this (Fig. 5) was to plot the difference in intensity over the longer wavelength part of the spectrum against that over the shorter (a plot of U-B v. B-V). Considerable information concerning the surfaces is then given by comparison with laboratory specimens as in Fig. 5. But a new technique has been developed

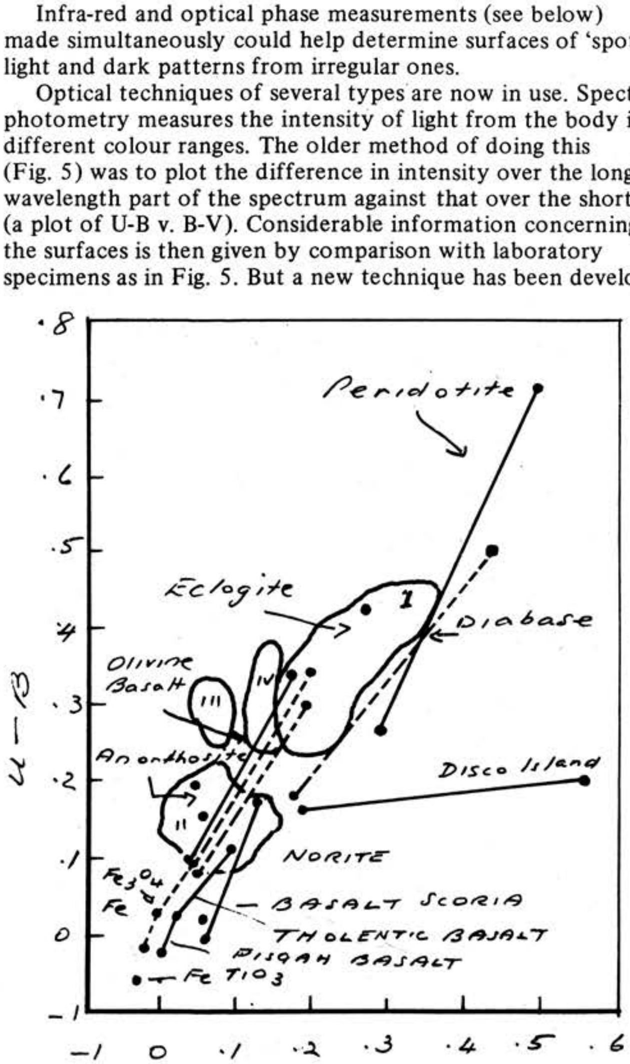


Fig. 5. Colour difference diagram. The asteroids are divided into four groups; I, II, III, IV, shown. They are compared to terrestrial rocks named. Filled circles = Solid material; open circles = powder finer than 37μm. Half-filled circles = powder coarser than 37μm. Similar comparisons have been made with lunar and meteoritic material (from Ref.A).

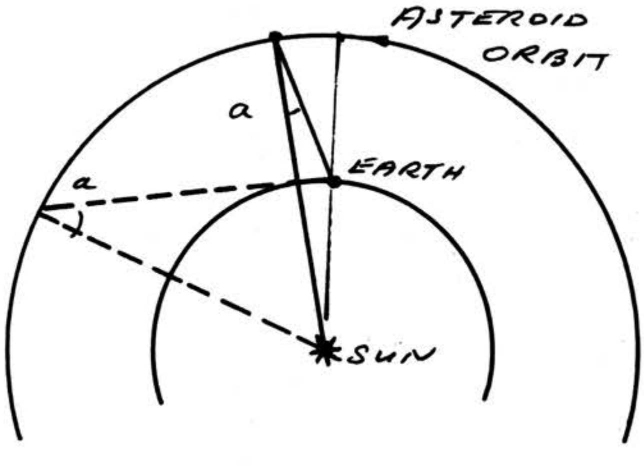


Fig. 6. Illustration of phase angle α subtended at asteroid as seen from Earth. Note the small ranges of these angles seen.

which promises far greater specification of composition than the rather looser generalizations of a U-B v. B-V diagram. An MIT team has used a 24-channel interferometer to give a narrow-range spectral analysis of the light from several asteroids. Even with this, unique compositional identification is probably not possible, but there is the opportunity of sorting the asteroids into compositional classes to see if they correspond to any of the classical groupings such as Hirayama families, or to see if there is a dependence with any of the orbital parameters. The Mars crossers, for instance, may be different from the main body. The observations of Vesta showed a surprisingly deep absorption band near 0.915μm that has been tentatively identified as a basaltic achondrite, agreeing with several other experiments. This of course only applies to the surface layer.

The surface layer is interesting, too, in the difference of opinion over the existence of a regolith. At first sight the low gravities of minor planets would seem to preclude the retention of a powdery surface layer. However, studies of the lunar regolith have shown that the vacuum accretion forces can be large, and may have been enough to retain the slower moving particles. Some optical properties, including the spectrophotometric ones, seem to support this latter conjecture. The generally low albedos indicate either solid surface or a powder of iron-rich material. The phase function slope, $\frac{dm}{d\alpha}$ = rate of change of visual magnitude with phase angle (see Fig 6.), for asteroids is steeper, in general, even than the Moon's, indicating strong back-scattering in a fine-grained, complex soil. The large 'opposition effect' – defined as an increase in brightness near $\alpha = 0^\circ$ over the general phase function – although not well understood, also seems to be more pronounced for fine powders. (If an olivine basaltic powder, for instance, the grains must be $\lesssim 50\mu$m). Polarization studies, too, suggest – in comparison with laboratory samples – a regolith of basaltic achondrite, though there are arguments over the usefulness of this technique.

All phase angle studies suffer from the small range of phase angles subtended at the asteroids from Earth. A fly-by vehicle could obviously extend the range of measurements to a full 0-180°.

Perhaps the most researched optical observations have been the photometric ones, that is those measuring the light-curve. This is the measurement of the change in light intensity with time. The variation will be the result of surface and shape irregularities of a rotating body. New mathematical models are being developed in an attempt to determine pole orientations and body shapes, though very refined methods will be needed to separate the effects of brightness variations from those of shape. Usually one has to be neglected with respect to the other. The rotation periods of many asteroids are now known, and estimates have been made of the shapes of those with the best determined light curves. Generally these are the ones which pass near to the Earth, such as 433 Eros, Geographos and 624 Hektor (See Fig. 7). The work on Hektor is interesting in that a review of light curve inhomogeneities, and considerations of probable material crushing strengths, has led to speculation that it may be a binary rotating system. All these models should, however, be treated with caution.

A lot of work with laboratory models has gone into trying to duplicate the light curves, but in general the lab curves are too smooth, indicating surface features are a significant part. One possibility for the future is that a simultaneous series of polarization/brightness measurements can help

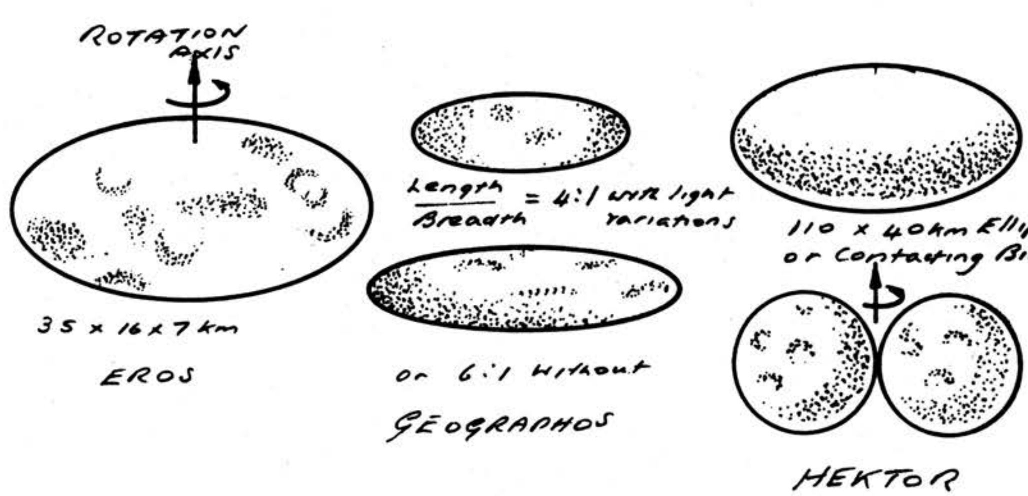


Fig. 7. Presently accepted estimates of shapes of three asteroids.

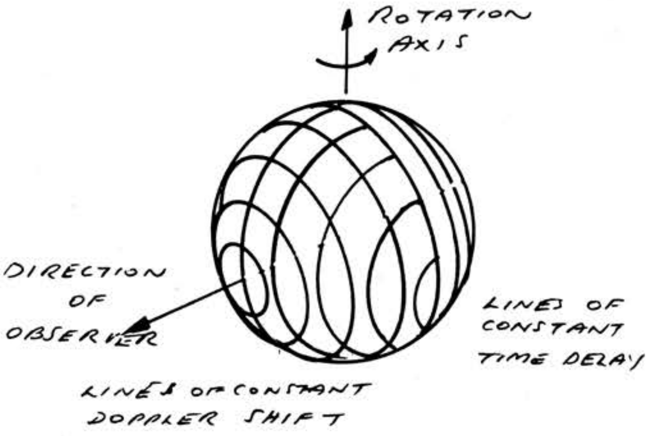


Fig. 8. Lines of constant Doppler shift and of constant time delay for observations on spherical spinning body.

distinguish rotation effects from those of changes in surface area.

Radio and radar measurements so far have been few and of little significance due to the small signals returned. Radar measurements on Icarus have been a useful tool for fixing its position, but no structural data was obtained. Doppler techniques will probably be the most useful in this field. Fig. 8 shows, for a spherical body with rotation axis perpendicular to the line of sight, the lines of constant Doppler shift, and those of constant time delay Fig. 9 shows a typical radar trace, modelled on the sort of signal that was returned from Mercury. The central frequency gives the relative velocity to 15 cm/s, the width of the spectrum the line of sight velocity of the limb. Surface roughness can be measured by polarization changes to the transmitted waves. Return signals have so far been too weak (i.e. too much noise) to give a worthwhile result, like these, for asteroids. More powerful equipment, such as the resurfaced Arecibo receiver, may be more successful.

Point Sources

We have seen above many cases where the small size of the minor planets is a distinct disadvantage in observations. There are some experiments, however, where this is very useful. As point sources, and small mass bodies, the asteroids seem ideal for determination of astronomical constants such as planetary masses, the astronomical unit and other distances, etc. However, technology has run ahead of the observational methods and the masses of Earth + Moon, Mars, Venus and soon Mercury, Jupiter and even Saturn, are better derived from the man-made probes sent across the Solar System [4]. The length of the Astronomical Unit is also now found by another technique – that of radar measurements on Venus.

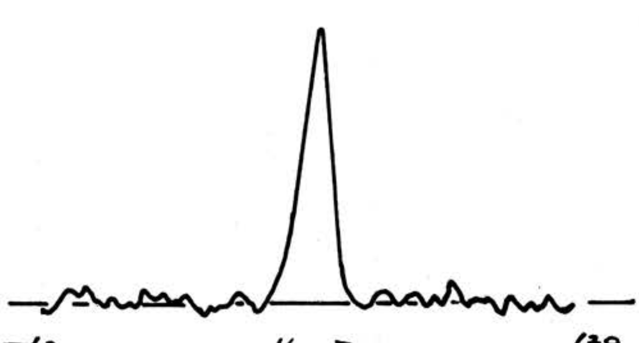


Fig. 9. Typical return radar trace from planetary body – modelled on observations of Mercury.

One field where the asteroids could become very important, however, is in corrections to the astronomical co-ordinate frame. In general, catalogued star positions are known to a high degree of accuracy with respect to surrounding stars, but positioning in the universal reference frame (the celestial sphere) is still not satisfactory. Theoretically asteroid observations could be used to refine the relative positions of the star maps, as they give a conveniently predictable and measureable connecting element as they move across the star background. This will entail deriving corrections to the Earth-Moon barycentre orbital elements, to the precession in longitude and Newcomb's rate of change of obliquity of the ecliptic.

Origins

The origin of the minor planets has long been a subject for conjecture. The theories have been dominated by the 'accretion' and 'fragmentation' accounts, the former having its more determined proponents in Russia. The main champions of the 'accretion' theory have been, of late, the Scandinavians Alfvén and Aarhenius, with the Americans supplying much of the experimental and theoretical evidence.

Accretion: It can be shown that a cloud of particles in orbit about the Sun will tend, by mutual interaction, to collect into streams. This has been dealt with more extensively elsewhere [5, 6], but can be seen in simple terms if we consider collisions in the cloud. The resultant products of a collision will tend to return, after an orbit of the Sun, to the same place, but with kinetic energy reduced by the interaction. Thus, in a rotating frame, the particles will appear to be under a gravitational attraction that has its centre at a median of the constituents' orbits, and about which they appear to oscillate. A series of collisions will reduce the relative kinetic energies and hence tend to bring about coalescence – an apparent viscosity effect.

It is this idea which is behind the accretion theory of asteroidal origin, and more explicitly, Alfvén's theory of 'jet-streams'. Opinions are divided as to the relative importance of this process when compared to collisions, the Poynting-Robertson effect (see below) and perturbations by other bodies, but there are important pieces of evidence in its favour. Perhaps one of the more remarkable is the work of Hills (Michigan) and others [7], who set up on a computer a model of the early Solar System, with a nebula of dust and gas surrounding the primordial Sun. The accretionary processes were programmed in, and a speeded-up history calculated. The results showed extraordinary similarity with the conditions we now see. A number of bodies were found to coalesce out. The distribution of sizes, when allowance is made for an over-abundance of smaller bodies due to collisions, fits fairly accurately the size distribution of the asteroids, and the number of terrestrial planets is approximately predicted. In

fact the asteroids and the terrestrial planets are shown to represent the two different end products of the same process. If one or two large bodies accrete before others can, they will tend to sweep up and eventually all the surrounding material, even if other coalition centres start to form. All bodies with mass greater than half that of Mercury are safe against break-up by collision as they acrete the other bodies. The end product is the terrestrial planets, with their characteristic distribution of craters. If, however, several bodies form more or less simultaneously in the same orbital volume, collisions among them will start to be important. A balance will be reached eventually between collisions and accretion with no extremely large body forming (thus the asteroids).

Other characteristics of the Solar System are modelled. Whereas collisions will not break up the larger bodies, enough energy can be involved to change the orientation of their spin axes. This would explain the inclination of Earth's and Mars' equators to the ecliptic, and the almost retrograde rotation of Venus. Also the coalescing material will have enough contraction energy for the bodies larger than Mars to melt. One other derived result is that if a body mass of $>0.003\ M_{\oplus}$ had formed in the asteroid belt, there would be only one body there now.

Of course such models suffer from the human tendency to put enough, and only enough, information in as to give the sort of answer that is being sought. Nevertheless this will take some answering.

There is other evidence in its favour, too. We noted earlier the argument over the existence or otherwise of regoliths on the asteroids and mentioned the vacuum accretion forces known to bring particles together under such conditions – bonding by condensation of silicates, sulphides and metal vapours, bonding by melts and shock lithification as well as van der Waals and electrostatic forces. As stated earlier there is a discontinuity in the minor planets' mass distribution at 20 km diameter, suggesting this is the borderline between accretionary and collisional fragments. The number distribution with size of craters on Mars, too, can be adequately explained by a bombardment at the present asteroidal/meteoritic flux rate, suggesting that its surface at least has only formed since the flux settled to its present level.

Yet more evidence is given by the distribution of spins of Solar System bodies – most are markedly similar in spin rate, to a factor of two (Fig. 10). Alfvén has attempted to show

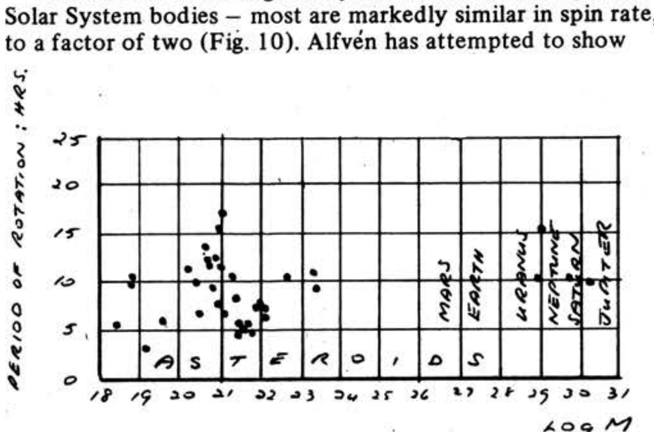


Fig. 10. Periods of rotation for some solar system bodies in relation to their masses (Alfvén 1964, 71).

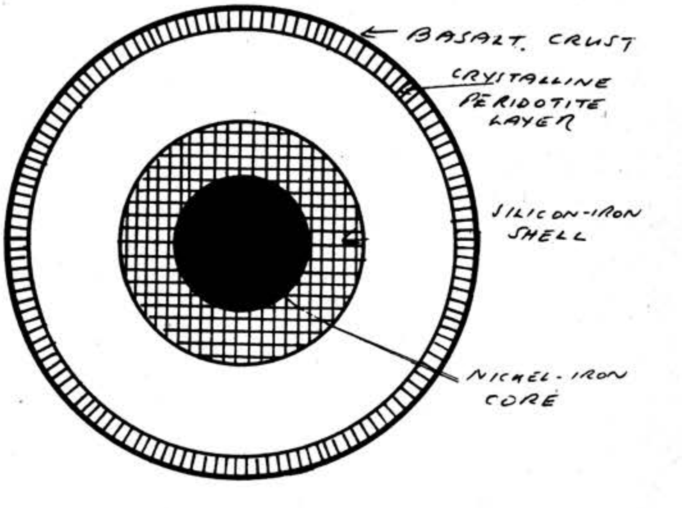


Fig. 11. The planet Phaeton before break-up, according to Krinov.

that the accretion model explains this, for, as each body grows it collects faster moving particles on the inner side of its orbit, and slower moving at the other. This, he says, will naturally lead to a spinning body, the spin rate of which is in the range indicated. Breakup fragments of a large spinning body, he claims, would be expected to have a wide distribution of angular velocities.

There is other evidence from meteorite orbit analyses that the iron ones come from 6-11 parent bodies, which are possibly also the source of the L-chondrites. These parents could be associated with seven asteroid families in the 1.9-2.8 AU range.

It would be unfair not to point out that each of the above points has a possible alternative answer. For instance, Whipple points out that the distribution of spin rates could be as they are because the higher angular velocities are unstable: nevertheless the low rates are found.

The Fragmentation Model: The theory that a large planet, previously orbiting the Sun between Mars and Jupiter, broke to give the asteroids, seems particularly favoured by Soviet scientists. They have, indeed, gone as far as naming this mythical planet Phaeton. Krinov's model of the planet [3] is shown in Fig. 11. A.N. Savaritski estimates the planet to have been of radius ~3,000 km and mass $\sim 1/15\ M_{\oplus}$

The hard outer shell is said to have broken up without going molten, thus giving angular fragments. The Peridotite shell, and probably the iron core, dispersed to a fine cloud of silicon and iron droplets surrounded by a gaseous mantle. Expansion led to cooling and hardening, the silicon droplets changing to chondrites, the iron to large crystals. Further processes of conglomeration and expansion resulted in the meteoritic bodies being hurled out. Thus, there should be a connection between the asteroids, meteorites and the short-period comets. This is considered in the next section. One problem encountered by this theory is that recent work, computing back from today's asteroidal orbits, seems to

indicate that these various bodies cannot have a common origin, though they may 'stream'.

Asteroids, Comets, and Meteors

The relationship between these is far from clear. Any such theory must be tied in with the distribution of small particles in the Solar System. We know there is dust around the Sun from the Fraunhofer corona and the zodiacal light, and the Gegenschein, or counterglow likewise demonstrates the existence of particles in the anti-solar direction. Besides these observations we have optical and radar measurements of meteor tracks, and the collection of fallen meteorites.

At the beginning of the last decade, it was believed that the dust was collected mainly in a cloud around the Earth – centred at the Lagrangean points, or as the 'tail' of the Moon's motion. This idea is now losing ground, but purely Earth-based measurements have not so far been able to determine the distribution unambiguously. The Gegenschein, for instance, may be due to an asteroidal dust cloud, but without the comparison of measurements from different viewpoints in the Solar System, this is hard to prove or disprove. This is the basis for the counterglow experiments being carried on Helios, Pioneer 10 and Pioneer 11.

A continuously-replenishing source is needed for all these particles, as, besides the daily meteorite falls on the Earth, the Poynting-Robertson effect is continually acting to diminish their number. (This latter effect is a loss of kinetic energy due to asymmetric re-radiation of solar energy, causing the particles to spiral into the Sun. Before they get there they are broken up by 'sputtering' and other mechanisms until solar radiation pressure becomes the dominant effect and the particles are driven out of the Solar System).

There is evidence that at least some of the meteors are asteroidal in origin. A few percent of stone meteorites have a noble gas component for which one explanation is implantation of solar wind ions into the regolith of their parent asteroid. If this is not the source, it is hard to see what is, as our Moon and the moons of Jupiter are too big to send large amounts of ejecta into space. There is also the apparent correlation between meteor showers and asteroid orbits illustrated in Fig. 12.

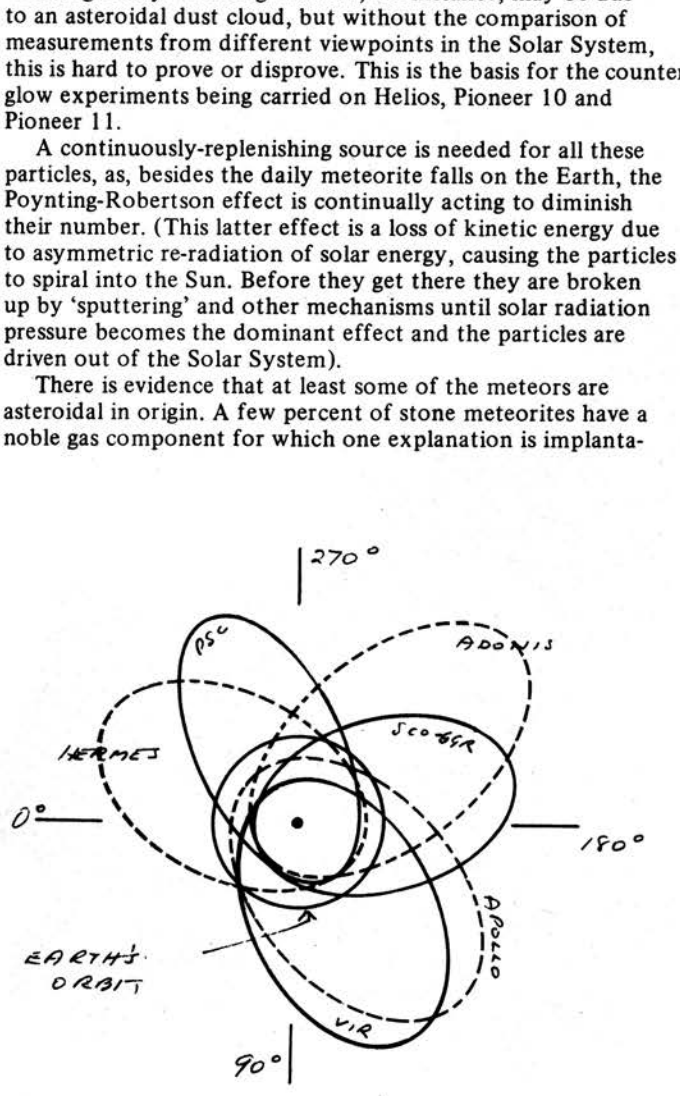


Fig. 12. Apparent correlation between meteor showers and Earth-crossing asteroids. Note similarity of orbital planes and tendency to merge if turned through 22° (therefore both result of a cometary fragmentation?).

There is, though, also plenty of evidence for cometary origin [2]. Ref. [8], which is to some extent a summary of recent evidence, fixes the probable proportions of origin at 90% comet, 1-10% asteroidal.

This leads, of course, to the question of whether there is any connection between the comets and the asteroids. The Earth and Mars crossing asteroids certainly seem different to the main body and may be cometary fragments or cores. This is supported by recent calculations suggesting there is a ratio of 10^4-10^5 of dynamic: evaporative lifetime for comets and the observations of at least two comets which have gradually lost their tails and aura, and thus looked more and more asteroidal. Comet P/Encke will probably look similar in 60 years. The non-gravitational effects on its motion (presumably due to the ejected material in its 'tail') seem to be diminishing with time. Note also that the large light variations of asteroid like Eros and Geographos would be expected if they were cometary fragments.

The Mars-crossers may not be the only asteroids connected with comets. The recent (re) capture of comet Slaughter-Burnham into an unstable or temporary Trojan orbit with Jupiter suggests that the Trojan asteroids cloud could be the origin of the Jupiter class of comets. 944 Hidalgo has a very similar orbit to these.

The Martian Satellites

Phobos and Deimos are interesting in their possible relation to the asteroids. They seem extraordinary satellites – apart from their extremely small size, their orbits are peculiar in their nearness to the primary. Phobos is near the Roche limit (inside which moons break up due to the internal stresses set up by the gravitational field of the primary), and is the only natural satellite to orbit faster than the primary rotates. Deimos is just beyond the synchronous orbit distance. There is evidence that Phobos' motion is due to terminate by impact in the relatively short (astronomically) time of 10 million years, though this has been questioned by Küiper and others who believe this prediction is based on erroneous observations.

Certainly it is tempting to look on these bodies as captured asteroids, but if this is true it is hard to think of a mechanism which could have circularized their orbits. One possible explanation, due to Singer, is that a large moon was originally captured into a prograde orbit, and that this crashed into the surface, splitting off the bodies we see now. In this case the photographs from Mariner 9 should show evidence of the catastrophic event.

Further on the subject of these photographs, those taken of Deimos have given considerable details of its surface – including its irregular shape and the presence of a large 'rift valley' around its midriff, probably the result of a collision or collisions. There is also evidence of a regolith from other observations [9]. Obviously, without being assured of a common origin, the extension of these observations to being evidence concerning the asteroids is dubious.

Interactions with the Solar Wind

The asteroids' interactions with the solar 'wind' will depend on the magnetisation of their constituent materials. For a minor planet to form a magnetosphere, bow shock, etc., in

this interaction (see Fig. 13), as is the case with the Earth, three conditions must be fulfilled:

(1) Magnetic field density must equal the 'pressure' of the solar wind at the surface of interaction (for a dipole field centred in the body $B^2/2\pi = nmv^2$).

(2) The field must extend at least the distance of its own proton gyroradius 'across' the solar wind, or there will be deviation and not halting of the plasma, and hence edge effect instabilities, making any barrier ephemeral.

(3) The field must extend 'upwind' a distance of at least the order of the mean of electron and proton gyroradii ($\sqrt{2pe}$), to reverse solar wind particles before they intersect the body.

If a dipole field is assumed,it is found that for larger asteroids a magnetic field large enough to hold the magnetosphere off the surface also fulfills the other conditions, while for the smaller bodies the limiting condition is that the field B must be big enough to give a magnetic cavity of dimension greater than p, the proton gyroradius. The crossover point of size between these two types is a body slightly larger than Eros.

For the larger objects B_0 at the surface of the order of tens of gamma is sufficient to form a magnetosphere, while even for 20-30 km bodies the 1,000 - 10,000γ needed may just be possible. Measurements on meteoric material suggest the smaller range of fields are possible, while Apollo lunar surface measurements indicate magnetisations 2-4 times that necessary for the larger asteroids (especially Ceres). So asteroids greater than 100 km radius have a good chance of having magnetospheres. Even more likely than a magnetosphere would be some sort of submagnetospheric interaction, even if the intrinsic fields of the asteroid materials do not add in a significant way.

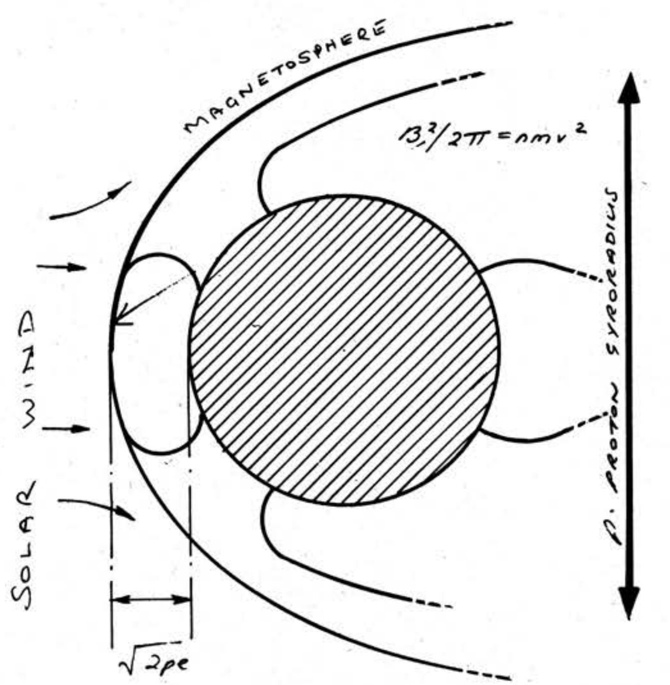


Fig. 13. Minimum conditions to be met for an asteroid to have a magnetosphere.

Probes to the Asteroids

The main points of contention among scientists interested in the asteroids does not appear to be whether probes *should* be sent to them, but *when?* Those who propose holding off until later reason that, waiting until present techniques are are exhausted, or at least have been more strenuously applied, may enable the first missions to be sent with a firmer theoretical and practical basis. Further Earth based studies tracing meteorites back to source may, for instance, indicate that it would be wasteful to send probes to the Mars-crossers as pieces of these already exist on Earth. The danger in basing any theories on the study of meteorites is that an unrealised bias may result due to the extremely selective nature of their interaction with the Earth. Only certain types can survive the passage through the atmosphere; fluffy aggregates would be broken up, soft surfaces melted off, volatiles driven out, etc.

The time for going aside, the observations which space probes could usefully make are generally agreed. Here could be a unique chance to study the primordial material of the Solar System. And this material is, in some cases, extremely close at hand. The Moon excepted, the Mars-crossers are our closest partners in space – Icarus came extremely close in 1968. The size range which asteroids occupy is also not yet studied. Eighteen orders of magnitude separate the Moon and the meteorites, and the asteroid size range is that where the crossover between gravitational and non-gravitational forces occur. If the accretionary theory is right then the asteroids represent an intermediate stage for the terrestrial planets and so will give information on their structures and histories.

There is no *a priori* reason why the 'Minor' planets should be any less interesting than the major ones; the lack of interest in them has generally been because so little *is* known of them.

The information which can be usefully collected may be summarised as follows:

(1) By Flyby

(a) Diameter, mass, density and albedo measurements of one or more asteroids would give a significant boost to Earth-based studies of the whole belt. Infra-red and optical techniques could then give far more meaningful results (especially if the shapes are also determined – say by TV observations).

(b) The question of the number distribution of the smaller bodies could be cleared up by flying imaging equipment through the belt (like the asteroid/meteor detector on Pioneers 10 and 11).

(c) Ambient background and interaction with the Solar Wind.

(d) Infra-red, photopolarimetry and spectrophotometry measurements possible at a far larger range of phase angles. Brighter, and so more accurately measured, images obtained.

(e) Gas envelope detection.

(f) The magnetic 'signature' of the surface may give information on the history of formation (and later) of the asteroids.

(2) By Landing

(a) Material samples from surface and interior, could

decide between accretion/Phaeton origins, test and connection with meteorites, and possibly give samples of primordial Solar System material changed only by fractionation of condensibles. As with the lunar samples the mineral and surface conditions may indicate totally new processes. No new materials were found on the Moon, but the processes governing their configuration and formation were completely new and largely unpredicted.

(b) Heat flow experiment, with others could indicate the thermal history. The thermal history of Eros, for example, could help determine if the Moon's heating 3,500 million years ago was a capture or other Earth-Moon event, or a more general astronomical environmental phenomenon.

(c) Knowledge of the body properties may clear up the question why all measured asteroids give no indication of coning motion – are they so elastic as for internal energy dissipation to have destroyed any coning motion they originally had?

(d) Landing of a transmitter, especially one with an accurately known frequency, on to asteroids that are otherwise detectable only near the Earth, or near perihelion, will mean their orbits can be plotted far more accurately, by observations on the transmissions at the larger distances, than is now possible. See comments above about corrections to the universal reference frame.

All this, of course, assumes that missions to asteroids are useful only in their intrinsic scientific role. There is as well, however, a good case for using a mission to an asteroid as a 'try-out', an intermediate step, in the programme to develop high-energy spacecraft. There are good reasons for sending an electric spacecraft to a near asteroid as a step in their development for planetary missions. Also, with present Apollo/Skylab facilities a close-flying asteroid is probably the only body other than the Moon which a manned vehicle could be sent to.

Information bearing on the asteroids can be obtained in other possible missions. The comets, for instance, are likely competitors for funds at this stage of space exploration, and as has been shown there may be links between these two phenomena. With space probes going to Jupiter it would be useful to clear up two points here: is there an asteroid belt in the Jovian system, and are the satellites largely uncratered due to initial accretion of only large bodies?

The second part of this article will examine the vehicles and experiments necessary to accomplish the asteroidal missions outlined above. There are several distinctly different ways to approach the question of vehicle type. Possible missions to the comets will also be discussed.

REFERENCES

A. *Physical Studies of the Minor Planets;* ed T. Gehrels; NASA SP267.
1. *Astronautics and Aeronautics,* Oct. 1972, Two articles: 'Why missions to comets and asteroids?' Fred L. Whipple and 'Two early missions to the comets', R. W. Farquhar and N. F. Ness.
2. *A Digest of Comets*, M. J. Hendri, pp. 32-37 *Spaceflight,* **13**, (4) Apr. 1971.
3. *'The System of Minor Planets'*, G. D. Roth (available BIS Libary).
4. 'A Solution for the Sun-Mars Mass Ratio Using Mariner IV Doppler Tracking Data,' G. W. Null, *Astron. J.*, **72**, (10) 1292 Dec. 1967.
5. 'Apples in a Spacecraft', H. Alfvén, *Science,* **173**, pp. 522-525.
6. 'Origin and Evolution of the Solar System', H. Alfvén, G. Aarhenius, *Astrophys/Spac. Sci.*, **6**, 338. 'Also 'Asteroidal Jet Streams', H. Alfvén, *Space Sci.*, **4**, 84, 1969.
7. 'The formation of the Terrestrial Planets', J. G. Hills, *Bull. Amer. Astron. Soc.*, **2**, 320 – see also Ref. A. pp. 225-237.
8. 'A Meteoroid environment for near-Earth, cis-Lunar and Lunar Operations, 1965', NASA TN D-2747.
9. Astronomical Notebook, *Spaceflight,* **14**, (9), Sep. 1972.

PULSATING CLOUDS OF VENUS

The top thick Venus cloud deck may move up and down more than one kilometer in a constant wave motion. That finding has been reported by a group of Jet Propulsion Laboratory scientists following infrared spectrum observations at JPL's Table Mountain Observatory in Angeles National Forest near Wrightwood, California. JPL is operated by the California Institute of Technology for NASA, which funded the study.

The astronomical team, headed by Dr. Luoise Gray Young, made its deduction of a fluctuating cloud bank after observations revealed a 20% variation in carbon dioxide absorption exists all over Venus. Other members of the team were Dr. Andrew T. Young, James W. Young and Dr. J. T. Bergstralh.

'The apparent strength of the carbon dioxide absorptions varied this much over a period of four days', the team reported recently in the *Astrophysical Journal.* 'The variations are synchronous over the disk, and thus represent a fundamental dynamical mode of the atmosphere'.

The Venus spectral tests were conducted last autumn using Table Mountain's 24 in. telescope and Coude spectrograph.

Infrared spectra showed the 20% carbon dioxide fluctuation to be a recurring four-day phenomenon. Previous ultraviolet observations by other astronomers had indicated that a four day cycle of some sort takes place on Venus.

'To produce the observed changes, the cloud tops must be moving up and down one kilometer all over the disk at once. We seem to be observing a fundamental feature of atmospheric dynamics that is not explained by current theories of atmospheric circulation on Venus'.

An extremely large amount of energy would be needed to produce this shift in the cloud-top level, the scientists said, adding: 'It is difficult to see where it can come from on a slowly revolving planet with low and spatially uniform absorption of solar radiation'.

Venus rotates only once every 243 days and is completely shrouded in cloud layers believed to be 15 miles (22 km) thick.

Oscillation of the cloud bank may be more closely checked by Mariner 10, to be launched this autumn and fly by Venus early in 1974 *en route* to Mercury. Both infrared and ultraviolet instruments aboard the spacecraft also can check constituents of the Venerian atmosphere, including carbon dioxide.

SKYLAB – THE DIARY OF A RESCUE MISSION

By David Baker

PART 2

Continued from September issue, page 340]

Shortly after 10 hrs GET, some 5 minutes before loss of signal through the Vanguard ship, the crew were instructed to undock, fly to the rear of the workshop and make an attempt to deploy the solar panel restrained by a 1 in. x ¾ in. strip of 7075 ST-6 aluminium angle iron.

More than 1 hour passed before the two vehicles were once again within tracking range. By this time, 11 hours 11 minutes after lift-off, the crew were struggling desperately with 'boat hooks' and other tools to free the jammed wing. Several times Weitz had pulled so hard he had disturbed the stability of Skylab causing it to rock gently before gyro's steadied the motion. With the oscillations threatening to pull him out the hatch and the two vehicles fast approaching sunset the first attempt to give Skylab valuable extra solar power had to be abandoned. Struggling to get back in the cramped Apollo,Weitz twice rammed the long poles against Conrad's helmet sending him under the couches for cover. Shifting down into the interior he chaffed against switches on the control and display console causing Kerwin to utter muffled words of abuse into the on-board recorders.

Out of contact yet again the spacecraft was manoeuvred into a docking position for the second time and a new problem was revealed. The docking latches designed to grip the centre cut-out on the drogue simply would not agree. Word on the problem first came at 11 hours 37 minutes into the flight with acquisition of signal over the *Vanguard* ship. More than 3 hours would pass before the two vehicles were finally hard docked. Donning helmets and gloves again for a depressurisation the crew had to open the forward hatch and realign the end plate on the probe, freeing the central shaft. With an electric jumper around the switching circuit the 12 latches on the docking ring would fire on contact and not await soft capture, impossible to obtain due to the stuck latches on the probe head. By firing up the RCS engines and thrusting the spacecraft forward the probe was centred on the drogue and simultaneously retracted as the two mating rings were driven together, triggering the 12 docking latches and achieving a hard dock. Another problem had been circumvented.

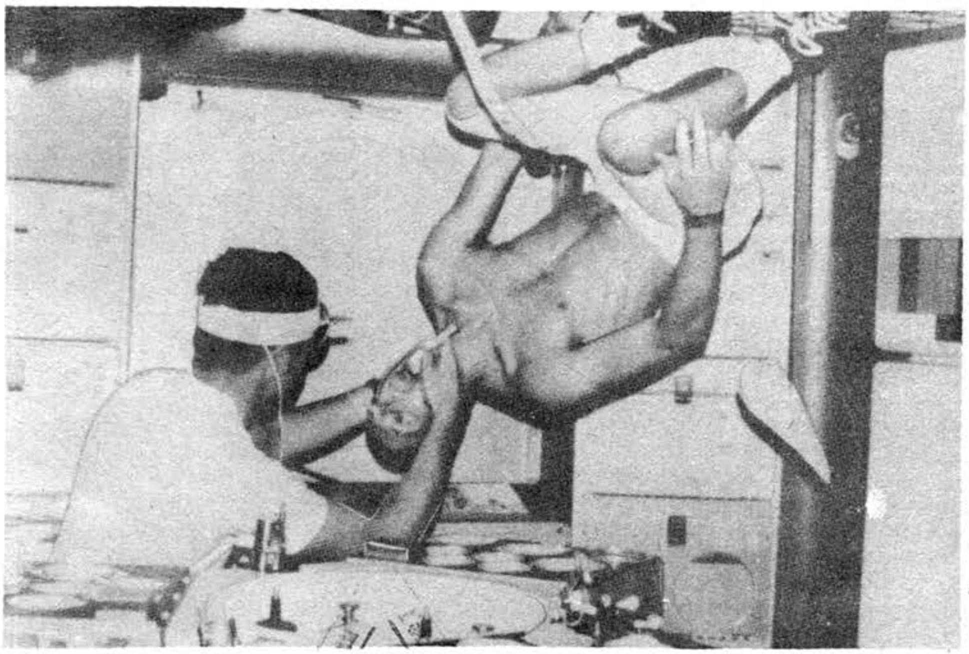
It had been a long 23 hour day since the crew had first awakened in the early hours and the 'goodnight' call to the crew came at 1:36 a.m. on the morning of 26 May, ending day 1 of the first mission to Skylab.

Mission Day 2:

A day devoted to cluster activation. Exactly 2½ hours after the first call to the crew at 9:05 a.m. the MDA was opened up with only 5 parts/million carbon monoxide detected. Kerwin and Weitz were busy in the MDA with Conrad shutting down systems in the command module. By mid-day Kerwin was activating the ATM console while Conrad and Weitz prepared to enter the AM and the OWS. Weitz was the first man into the OWS, at 1:23 p.m. and by 3:00 p.m. all had returned to the MDA/AM using this as the habitable area, isolating the OWS due to the high temperatures. After an eat period at 3:15 p.m. Conrad and Weitz entered the OWS again to begin deployment of the parasol at 4:15 p.m. With live TV covering operations from the window of the command module the parasol deployment was completed by 7:30 p.m. with all the rods extracted by about 9:00 p.m. The cluster was orientated to a solar inertial attitude (ATM panels facing the Sun) by 9:50 p.m., and all the hatches left open for air circulation as the crew said goodnight to the ground at 12:10 a.m., 27 May. They were to sleep in the command module.

Mission Day 3:

Awake at 7:24 a.m. the crew would spend most of the day stowing lockers, etc. from the launch configuration, checking out the ATM (by ground commands) and preparing for experiment activity on subsequent days. Food was still



Floating upside down in the orbiting Skylab space station, Pete Conrad undergoes a physical examination, including a throat check, from Dr. Joseph Kerwin. The medical testing is a major objective of the manned missions.

United States Information Service

being prepared from the command module and the first OWS television pictures were transmitted from 9:35 a.m. to 9:53 a.m., and once again at 11:13 a.m. for the activation of the wardroom, waste management compartment and sleep compartments. During lunch, at 1:00 p.m., the advertised news conference was deleted and a space/ground conversation held on the possibilities of deploying the single OWS solar array boom. Some 4.6 kw electric power was available from the ATM arrays with 3.6 kw devoted to systems management and 1.0 kw available for experiments. For comparison, at full power the ATM requires 0.7 kw, EREP 0.45 kw and the medical equipment 0.4 kw. By 3:00 p.m. the ambient gas temperature in the OWS was down to 36.5°C and falling, with the maximum food locker temperature reading 45°C. At 4:08 p.m. another TV transmission was beamed to Earth, with the goodnight call from the ground at 9:05 p.m. The crew slept in the MDA using sleep bags slung like hammocks.

Mission Day 4:

Communications with the ground began at 6:00 a.m. with breakfast in the wardroom at 7:30 a.m. followed by completion of cluster activation and stowage transfer. Attention focused on the activation of the medical equipment, with a TV transmission at 10:30 a.m. Another TV transmission at 12:07 p.m. showed meal preparations in the wardroom followed by the press conference postponed from the previous day. Kerwin reported he inadvertently left power switched on to the waste product scales 'last night' and burnt out the electronics. A second device would be transferred from the wardroom. By 2:19 p.m. the ground checkout of the ATM was complete and the rest of the afternoon was spent in preparing medical apparatus. Conrad spent time in the LBNP device followed by a run on the ergometer. The activity began at 5:00 p.m., monitored by Kerwin and terminated early due to excessive heat in the OWS. Also today, blood samples were drawn and the body mass measurements was calibrated. At 8:07:36 a 1 minute 3 second service module RCS burn trimmed the orbit by 2.1 ft/sec. with final space/ground at 10:30 p.m. The crew slept in the MDA with temperatures in the OWS at 31°C. No food from the wardroom had thus far been consumed.

Mission Day 5:

Today marked the first full operational capability of the cluster, with the crew up at 6:05 a.m., Weitz on EREP checkout by 8:00 a.m. and Kerwin powering up the ATM for 4 scans during the day. At 9:18 a.m. Conrad held a private conversation with the ground on medical and operational planning and an alignment check on the ATM deployment showed it to have latched within 0.1° of true. At 1:08 p.m. a stability malfunction in the ATM experiment canister kept Kerwin busy for the remainder of the day, only taking a break to monitor Conrad on the LBNP and ergometer at 3:30 p.m. The EREP activation and checkout revealed problems with several of the scanners promoting a malfunction run-down until 6:30 p.m. Earlier, Weitz had monitored Conrad on the LBNP. During the evening, at 9:05 p.m., Conrad reported on the exercise they obtained by 'running' round the ring of water canisters in the OWS dome and by 9:58 p.m. the crew were preparing to spend their first night in the sleep compartment of the crew quarters. Kerwin wore the sleep monitoring harness. Today the ambient OWS temperatures dropped to 29.5°C. and on this first day of experiment runs an average 4.4 kw was drawn from the ATM arrays. Consideration was being given on the ground to projecting the single TV camera through the anti-solar airlock on poles to view the parasol and check its physical integrity.

Mission Day 6:

A crew call went out at 6:01 a.m. and by 8:50 a.m. Kerwin was activating the litter chair used for vestibular function tests. Use of the chair was terminated early due to power considerations. At 9:00 a.m. Conrad began work at the ATM console, relieved by Kerwin at midday. At 3:35 p.m. the first full EREP pass (23 min.) began on 25 sites running from the coast of Oregon down to Brazil on revolution track 20. With the cluster in a local vertical hold and the 17 remaining Charger Battery Regulator Modules unable to draw power from the solar arrays (1, No. 15, had malfunctioned days before) during the EREP pass, Skylab swept into night out of ground contact. When Skylab came back into acquisition five CBRM units were off line with the remaining 12 already well down on charge due to the inclement attitude. CBRM units 6,7,8 and 16 were brought back on line, drawing power from the ATM array and charging the batteries back up. These four had disconnected due to a low-voltage trip even though the voltage had been held to 45% charge when the redline was set at 20%. CBRM number 3 refused to switch its regulator in on repeated commands and remained off line bringing the total number of effective CBRM units to 16 from the planned 18. This removed a total 12% from the energy budget profile with each CBRM lost lowering available power by about 200 watts. To date the crew had done well in conserving power, running an average of only 10 out of an available 72 lights, and de-freezing food by leaving it out in the wardroom. This latest electrical problem added urgency to the need to deploy the OWS boom and immediate run-down plans in Mission Control included a deletion of further EREP passes and curtailment of corollary experiments.

By 5:15 p.m. the crew were busy removing the probe head assembly in a trace of the docking problem on Day 1 and at 8:30 p.m. Weitz configured the ATM for unmanned runs during the crew night. At 9:02 p.m. the ground said goodnight

Repair men at work. Skylab astronauts Pete Conrad (left) and Dr. Joseph Kerwin work outside the orbiting space station to repair the partly deployed solar wing. After a struggle the astronauts cut a constricting metal band and pulled the surviving panel open.

United States Information Service

ABBREVIATIONS	
LBNP	Lower Body Negative Pressure device.
ATM	Apollo Telescope Mount.
EREP	Earth Resources Experiment Package.
OWS	Orbital Workshop.
EVA	Extra Vehicular Activity.
CBRM	Charger Battery Regulator Module.
MDA	Multiple Docking Adapter.
TCVB	Thermal Control Valve-B.
CSM	Command and Service Modules.
RCS	Reaction Control System.
SPS	Service Propulsion System.

to the crew with Kerwin again wearing the sleep monitoring apparatus. For all effective planning purposes the cluster was now down to little more than 4.0 kw power availability and several technical discussions were under way in an attempt to circumvent this latest problem. Skylab had reached a new low and without deployment of the solar array boom the full 28 day flight would be seriously imperilled.

Skylab clippers. A metal cutter similar to the one used by the Skylab crewmen to free the stuck solar panel is demonstrated by astronaut 'Rusty' Schweickart during a Press Conference at the Johnson Space Center in Texas. The device was mounted on the end of a long pole held by crew commander Pete Conrad. Dr. Kerwin then pulled the lanyard to complete the cutting operation.

United States Information Service

Mission Day 7:

On the first day of the most conservative electrical budgeting thus far the crew were called through the Carnarvon station at 6:02 CDT and by 8:00 a.m. Conrad was at work on the ATM console with the minimum number of fans and lights turned on. By mid-morning calibration of the body mass measurement experiment was complete and a malfunction run-down procedure had been completed on SO-19. Following lunch at 12:00 midday Conrad returned to the ATM console and Kerwin and Weitz completed three runs on the rotating litter chair. By 4:30 p.m. Weitz was performing on the LBNP and ergometer and discussion was entered into on the possibility of projecting the TV camera from the anti-solar scientific airlock on Day 8. This was cancelled by 8:00 p.m. Much of the evening was spent in discussing OWS solar array boom deployment techniques, with a final goodnight to the crew at 10:10 p.m Electrical loads this day had run at about 3,700 watts v. a predicted 4,000 watts, the balance being saved by on-board conservatism. Temperatures were now down to 27.5°C.

Mission Day 8:

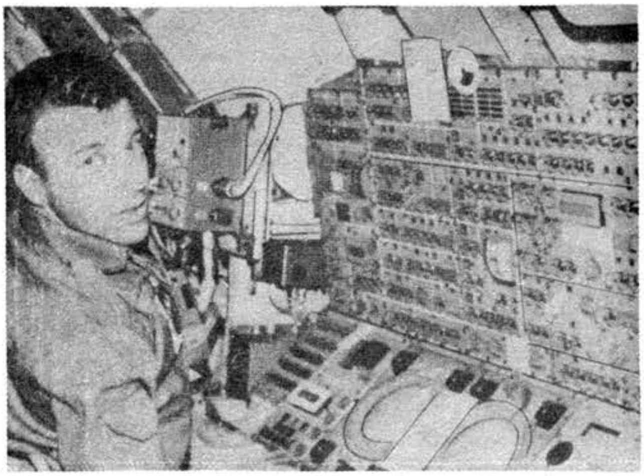
A day off for the crew, with a call from the ground at 8:43 a.m. and most of the morning spent in housekeeping duties and stowage activity. Lunch at 12:00 midday was followed by an out-the-window description of the Earth. Deke Slayton briefed the crew on solar array boom deployment procedures for several days hence and at 2:07 p.m. a 16-minute TV show began with recreation underway including the water-ring exercise of 'running' around the tanks. Late afternoon Weitz, Kerwin and Conrad took showers in that order and two erroneous alarms came before the goodnight call at 10:52 p.m. Temperatures were now 27.3°C.

Mission Day 9:

Today marked the Commander's birthday and a wake-up call went out at 6:16 a.m. By 10:30 a.m. activity on the LBNP and vectorcardiogram was underway, with S-183 running at 12:47 p.m. followed by S-009 and EREP checkout at 1:20 p.m. The 10-minute pass from 133°W to 100°W was begun at 3:04 p.m. scanning 35 sites with all sensors except the electric terrain camera. At 3:30 p.m. the electronics package to the waste measurements device was transferred from the waste compartment to the wardroom. At 6:41 p.m. Conrad's wife and 4 children spoke to him during the Vanguard pass. More than 4.5 ATM hours were accomplished with a final call from the ground at 10:23 p.m. Temperatures in the OWS were now down to 26.2°C and 47% propellent remained in the attitude control thrusters on the rear of the workshop. On the ground Schweickart ran through solar array deployment procedures in the water tank at the Marshall Space Flight Center and a management decision to finalise the approach at deployment was promised for Day 12.

Mission Day 10:

The crew were woken up at 6:11 a.m., had breakfast at 7:15 and began the days events with ATM work by Kerwin. One of the aperture doors on the ATM canister had stuck necessitating a work-around procedure and a 16 minute TV transmission from the wardroom window began at 12:43 p.m. The third EREP pass began at 2:22 p.m. lasting 11 minutes. A master alarm in the command module indicated a 14 lb. drop in LOX pressure with no problem. By 4:15 p.m. Kerwin had concluded a run on the LBNP/vectorcardiogram while Weitz was manning the ATM. Conrad had observed the degradation of the parasol and reported it to be yellowish gold in colour. Houston responded by confirming that the array boom deployment procedures would be uplinked on the teleprinter tomorrow. With Kerwin wearing the sleep monitoring device the crew were bid goodnight at 9:35 p.m. Temperatures in the OWS were now 25.5°C. Two methods of increasing the electrical power availability had been determined, should the solar array boom deployment fail. McDonnell Douglas had developed a roll-up array for deployment from the CSM of SL-111 (Mission 2), while Rockwell International had proposed the launch of a solar array device attached to the Apollo-Soyuz Test Project docking module and affixed to the radial docking port on the multiple docking adapter.



Telescope control. Skylab astronaut Paul Weitz sits at the control and display panel for the Apollo Telescope Mount (ATM) aboard the space station. The ATM is the first manned astronomical observatory for performing solar research from Earth orbit. It also has a four-panel solar array that generates about half the workshop's electrical power and houses the primary stabilization and attitude control components for the total spacecraft.

United States Information Service

Mission Day 11:

The crew were awake by 6:35 a.m. and proceeded directly to EREP checkout with Kerwin and Weitz moving to the ergometer device mid-morning. EREP-4 began at 12:04 p.m. for a 3,000 mile pass. Aircraft performed an underfly calibration during this experiment but a calibration rocket was destroyed by the range safety officer shortly after launch. In the afternoon Kerwin was busy at the ATM console while Weitz used the vectorcardiogram. ATM work continued on apace into the evening followed by an extensive EVA briefing by astronaut Schweickart at 9:25 p.m. The last call to the crew came at 9:38 p.m. Temperatures in the OWS were down to 24.5°C during the day and a trickle charge into 4 OWS batteries (Nos. 5, 6, 7, 8) had brought up one to 100% charge and a second to 72%. These were still not feeding any loads and the CBRM units fed from the ATM arrays were never allowed to drop below 70% following the low-voltage cut-off on Day 6. During the day Conrad had requested that the next two rest days be deleted from the flight plan to compensate for the upcoming EVA to deploy the boom. To date Conrad and Kerwin had lost only 1 lb. in weight, while Weitz had lost 4 lb. Each crewmember was maintaining his 2,500 calorie intake per day and medical reports were excellent.

Mission Day 12:

Awake and communicating by 6:20 a.m. the crew went to work on ATM activities with Weitz manning the console, followed by Conrad and Kerwin on the LBNP and ergometer by 10:00 a.m. The fifth EREP pass started at 12:57 p.m. covering 30 sites in a 2,800 mile sweep, terminating at 1:09 p.m. In the afternoon Conrad manned the ATM while Kerwin monitored Weitz on the rotating litter chair. After the evening meal at 6:00 p.m. further discussions were held on the upcoming solar array boom deployment EVA and plans were laid to spend Day 13 rehearsing the procedures with TV on from the OWS. Just before going to sleep at 10:00 p.m. CBRM-17 showed a 4-amp reduction with a 3.1-amp reduction on regulator switching. During the day all crewmembers had performed the mineral balance experiment and bioassay of body fluids, Conrad had used the LBNP, vectorcardiogram, and ergometer, while Kerwin had worn the sleep monitoring device. Still obtaining a trickle charge from the partially deployed OWS solar array boom batteries 5 and 7 now had 100% charge, battery 6 95% charge, and battery 8 50% charge, with all loads borne by the CBRM units slaved to the ATM arrays. The temperatures in the OWS now stabilised at 24.2°C.

Mission Day 13:

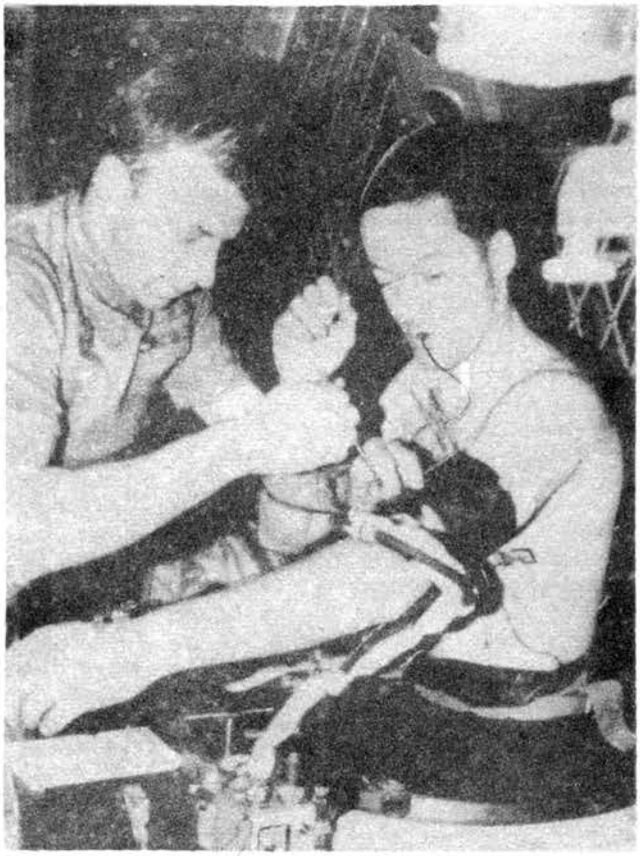
Houston sent a 7:15 a.m. call to the crew to learn that they had spent 1½ hours on the previous evening laying out the solar array deployment equipment in readiness for the rehearsal today. The entire morning was spent on EVA discussions with Schweickart, astronaut Gibson and the crew reviewing tomorrow's activity. After lunch EREP-6 began, at 1:55 p.m., with a 5 minute pass starting of Baja, California. At 1:58:20 p.m. Kerwin used a hand-held Hasselblad camera to shoot film of Hurricane Ava using 70-mm and 100-mm lenses for oblique views. At this time also a C-130, fully laden with fuel for stability, flew through the 'eye' of the hurricane to monitor the storm and supplement the spaceborne information. The crew could clearly see down the 30,000 ft. funnel of the eye. The afternoon and evening hours saw Kerwin busy on the LBNP, the vectorcardiogram, the ergometer, and he was joined by Conrad and Weitz in the blood sample collection. A total of 2 hours 9 minutes ATM work had been accomplished and the late evening was spent in reviewing tomorrow's EVA procedures. The last call to the crew came at 9:05 p.m. During the day the troublesome CBRM-17 settled back to normal providing Skylab with a level 4,000 watts available power. Mission Control also advised the crew that the EVA would require 1012 watts from the Skylab systems and already power-down procedures promised to off-load the cluster by 1106 watts, more than compensating for the requirement.

Mission Day 14:

The crew were awake by 6:02 a.m. and began preparations for the EVA necessary to attempt deployment of the solar array boom. After beginning depressurisation at 9:48 a.m., Weitz was required to go back into the workshop and turn off extra lights while ground control watched the power levels. The hatch was finally opened at 10:23:20 a.m. with contact through the Ascension Island tracking station. Conrad and Kerwin exited the airlock module and began the Stateside pass at 11:27 a.m. with live TV through the window. Sixteen minutes later, still working to attach a cutter to the strap that would be played out as Conrad edged his way along a pole to the boom, Kerwin's heart rate was 150/min. and Conrad's 110/min. Loss of signal came before the cluster flew into the night-side of Earth at 12:10 p.m. At 11:57 a.m. Conrad had started down the pole to the boom and was expected to rest during the night pass before attempting cutting operations and deployment. However, at 1:03 p.m., 18 minutes into sunrise, communications at Goldstone indicated that he had cut the retaining strap and pulled the boom free, permitting it to rotate out the desired 90° at a tip speed of 0.82 ft/sec. Two of the solar array panels then deployed to the 40% position and one to the 30% position. Indicated deployment time was 12:55-1:00 p.m. By 1:18 p.m. Conrad

and Kerwin were back in the fixed airlock shroud around the airlock module and confirmation of ingress was obtained through the Hawaiian tracking station at 2:37 p.m. At 4:30 p.m. the cluster was pitched down 45° to bring solar heat to the 'frozen' array linkages, permitting them to fully deploy 100% by 7:58 p.m. During the EVA Conrad had replaced the film canister on the Coronal Spectroheliograph telescope in the ATM, and latched a sticking door to the X-ray Spectrographic telescope. Average metabolic expenditure rated Conrad at 1080 Btu and Kerwin at 1700 Btu. Heart rates averaged 96 and 118 respectively. Skylab was back in solar inertial attitude at 8:05 p.m. and the evening meal commenced 10 minutes later. Weitz was at the ATM console by 8:39 p.m. for a 49-minute pass and by 9:00 p.m. the crew were running malfunction procedures on a coolant loop problem that had emerged prior to the EVA.

Running on the secondary coolant loop for much of the flight the primary loop was switched on prior to the EVA, indicating a mixer valve stuck in the fully cold position and rapidly bringing the whole loop down in temperature. The primary loop was turned off with a shock to the secondary loop due to power-down procedures reducing the temperature, freezing the capacitor and by 7:00 p.m. approaching the



Skylab astronaut Paul Weitz (*left*) assists Dr. Joseph Kerwin in adjusting a blood pressure cuff during one of the medical tests aboard the orbiting workshop. The cuff is used with a 'lower body negative pressure device' designed to provide information on cardiovascular adaptation to space flight and its after-effects upon returning to Earth.

United States Information Service

critical temperature value for the entire loop. When power levels rose in the solar inertial attitude the secondary loop threatened to switch in the primary. Assuming the temperatures would level off before critical values were reached the crew went to sleep at 10:12 p.m. with the secondary loop turned off, permitting it to warm up gradually. When the heat exchangers had dropped to -1.1°C, the crew were woken and requested to plug in the liquid cooled garments with a long umbilical from the OWS to the airlock module. From a maximum low of -35°C the thermal capacitors began to warm up and by 12:30 a.m. the crew finally settled down. The only medical experiments conducted on this busy EVA day were the mineral balance and bio-assay of body fluids. The successful deployment of the single OWS solar array boom had provided a near-80% increase on the total available electrical power and the mission could henceforth assume a reasonable standard of normality.

Mission Day 15:

The crew were woken up at 7:58 a.m. and were soon at work changing an airlock module tape recorder which had malfunctioned during the night. A discussion on the Day 26 film retrieval EVA, and the possibility of deploying the MSFC A-frame solar shield, preceded an ATM TV downlink at 10:30 a.m. Showers were taken at midday with ATM activity picking up the early afternoon hours. By 3:30 p.m. Weitz was working as test subject on the LBNP and ergometer, monitored by Kerwin. More ATM followed, with Conrad and Weitz taking showers at 5:40 p.m. By 9:00 p.m. an EVA debriefing was underway immediately followed by coolant loop rundown procedures. Switching the primary loop on to determine the unfreezing effect of a coolanol flow, the crew were unable to free the stuck valve and diverted flow back to the secondary loop. The final call to the crew ended at 10:00 p.m.

For most of the day the OWS solar array delivered 1750 watts into the eight Power Control Groups, the OWS equivalent of the ATM's 18 CBRM's, peaking at 2,700 watts during the afternoon. Some 360 watts was being cross-fed into the PCG's from the CBRMs to supplement the OWS power. In addition to the LBNP and ergometer Weitz had used the vectorcardiogram during the day with mineral balance, bio-assay of body fluids, and time and motion studies performed by all three. The OWS temperature was now showing 23.75°C, compared with 24.2°C earlier.

Mission Day 16:

The crew were awake by 6:15 a.m. and preparations began for the seventh EREP pass of the flight. The 28-minute run began at 10:02 a.m. for a 25 site pass across 6,000 miles from Washington state to the Atlantic Seaboard. By 11:35 television was recorded of Conrad in the LBNP and at 12:06 p.m. a discussion of the coolant loop problem prompted the crew to repeat the unfreezing test of yesterday, this time with two pumps running simultaneously. By early afternoon the valve had been freed and both loops were showing recovery. By late afternoon the medical runs had been completed and; during the day Conrad had worked on the LBNP, vectorcardiogram, and ergometer, with Weitz operating the vestibular chair. During the night Kerwin would wear the sleep monitoring equipment. Some 4 hours 8 minutes of ATM activity had been completed with several corollary experiments run. OWS temperatures stabilised at 23.0°C although Conrad thought at one point the level was rising.

Mission Day 17:

Up early for an EREP pass the crew were active by 5:30 a.m. The 27 minute, 6,500 mile pass began at 9:19 a.m. and successfully met 28 task site objectives. The balance of the morning was spent in ATM and medical experiments. At 2:35 p.m. Weitz reported a malfunction in the nuclear emulsion experiment and Conrad conducted ATM operations while Kerwin and Weitz performed more medical experiments. At 8:27 p.m. the ATM control officer reported a possible malfunction in the White Light Coronograph but this was unconfirmed as the crew last spoke to the ground at 9:39 p.m. During the day Kerwin had operated on the LBNP, the vectorcardiogram and the ergometer, with all three crew working the mineral balance and bio-assay experiments. Weitz had used the rotating vestibular chair. Some 4 hours 57 minutes ATM science had been obtained.

Mission Day 18:

The wake-up call went out at 6:18 a.m. and by 6:30 the crew had reported a stuck aperture door on the White Light Coronograph. A mid-morning EREP pass over the continental United States ran for 28 minutes along a 7,700 nm groundtrack followed by more troubleshooting activities on the coolant loop. This time a secondary loop valve had stuck and the second valve was activated with the first still running, admitting a pressure of 75 psi. With both turned on, warmed to 10°C, and an operating pressure of 200 psi going through the plumbing the valve remained stuck. Some 4 hours 37 minutes ATM activity was completed this day, with Weitz performing with the LBNP, ergometer, and vectorcardiogram while Kerwin occupied the rotating litter chair. The crew got a 'goodnight' from the ground at 9:28 p.m.

Mission Day 19:

The crew were awakened at 6:00 a.m. and began immediate preparations for an EREP pass lasting 27 minutes. Principal objectives included study of a storm front south of the Great Lakes, looking at chlorophyll blooms off the east coast and analysing a cumulous build-up with intertropical convergent zone weather systems in the Atlantic. Some 23 sites were surveyed in all from 100°W to 28°W. After EREP activities the ground commanded a 400 psi pressure through both secondary coolant loop pumps, successfully freeing the jammed valve. Later in the morning hours Conrad initiated operation of the metals melting task using a vacuum chamber in the multiple docking adapter, using this facility for welding operations. Minor problems were noted in connection with the electron beam gun, but continued afternoon activity solved all major problems with several satisfactory tasks being accomplished. The crew were bid goodnight at 9:49 p.m. During the day Conrad was test subject for the LBNP, ergometer and vectorcardiogram with some 5 hours 41 minutes ATM operations completed.

Mission Day 20:

A wake-up call was transmitted from the ground at 6:00 a.m. and at 8:12 a.m. 2 minutes recorded TV of the Moon was shot. The penultimate EREP pass, the 10th of Mission 1, began at 8:42 a.m. and continued along a 7,400 nm groundtrack for 32 minutes, surveying 14 sites and looking at severe storm conditions in the Mississippi delta, urban growth in Florida and sea state conditions along the Pacific coast. The valuable increase in total electric power availability was displayed by the 5000 watt usage during this activity, still 2000 watts under the maximum available. Over the midday hours sphere forming activities were accomplished using the vacuum chamber in the MDA. During the afternoon Conrad and Kerwin took turns on the litter chair operating at rotation rates of 20 and 25 rev/min. respectively. The crew were bid goodnight at 9:49 p.m. Operationally, Skylab continued in good shape with more than 7000 watts power available. However, several minor 'glitches' continued to plague this initial run-down mission with a spurious amperage signal from the secondary coolant loop in the CSM reported during the evening hours. More than 4 hours 51 minutes ATM activity had been accomplished with a complete physical examination performed by Kerwin on Conrad and Weitz pronouncing them exceptionally fit.

Mission Day 21:

The crew were up shortly after 5:00 a.m. and communicated with the ground at 6:09 a.m. One of the first tasks of the day was to operate the sphere forming experiment in the materials processing facility, an operation performed by Conrad. The final EREP pass, a 28 minute 7000 mile run, began at 9:40 a.m. and conducted studies of volcanic and other geologic activity across the United States. Shortly after midday the crew performed an operation that has only been conducted once before, and that on the near fateful Apollo 13 – the three fuel cells were shut down. With some 1100 watts now being fed across to the CSM buses and the OWS running on 4700 watts a balance of 1200 watts still remained. All cryogenic hydrogen had been depleted but the 169 lb. of cryogenic oxygen would now be fed into the OWS at a rate of 13 lb/day. From a launch on Day 1 some 4 hours earlier than that scheduled pre-mission the circadian adjustment for the crew's day/night cycle began with an early start to the rest period. They began this sleep period 2 hours earlier, at 7:54 p.m., and would wake up 3 hours early at 3:00 a.m. shortening the sleep period to 7 hours. During the day Weitz was subject for the LBNP, ergometer and vectorcardiogram runs with about 4 hours 39 minutes ATM activity. One of the student experiments, the bacteria and spore growth task, was activated during the afternoon. Today the electrical power availability stood at close to 7000 watts, with an average 6500 watts drawn for all applied loads. The increasing beta angle, the angle formed by the plane of the orbit versus the Earth-Sun, continued to shorten the periods eclipsed by the Earth's mass, thus increasing the solar exposure time. With four CBRM units (6, 7, 8, and 16) delivering only 10-12 amps against a nominal 20 amps the mission would have been terminated prior to cryogenic depletion had the crew been unsuccessful in deploying the OWS solar arrays. The only major anomaly on Day 21 was a 10 psi drop in pressure within water tank No. 7. On the ground a comprehensive management review was held to discuss the possibility of Conrad and his crew deploying the MSFC A-frame solar shield on the Day 26 film retrieval EVA. This activity was deferred to the next mission.

Mission Day 22:

Awake by 3:00 a.m. the first call from the ground came at 3:50 a.m. and the crew were advised that NASA management had requested a possible EREP pass on Day 25, to be confirmed later. Today the crew performed Entry Interface – – 7 days checkout of the CSM, preparing for a full 5½ hour entry simulation on Day 23. Some 6 hours 18 minutes ATM work also saw considerable attention devoted to a solar flare

with Weitz at the console during this phenomenon. Brazing and sphere forming tests were also completed, and medical tests saw Conrad on the LBNP and vectorcardiogram, with Kerwin riding the rotating litter chair. The crew officially began their sleep period 2 hours earlier than the previous night, at 6:00 p.m., thereby stepping back a total of 4 hours from the normal sleep start of 10:00 p.m. The now familiar secondary coolant loop TCVB valve once again froze up and yet proposed no major malfunction beyond the operational annoyance.

Mission Day 23:
The final readjustment on wake-up times was completed with the start to the day beginning at 2:00 a.m., providing the crew with the nominal 8 hour rest periods and effectively backstepping the required 4 hours. Much of the activity centred around the entry simulation with the crew performing a full dress rehearsal of de-orbit and entry procedures. During the crew's afternoon hours more exothermic brazing and sphere-forming experiments were conducted and Kerwin was test subject for the LBNP, ergometer and vectorcardiogram. Weitz used the vestibular chair. Despite the heavy CSM activity some 2 hours 17 minutes ATM activity was completed and the crew started their sleep period at 5:51 p.m.

Mission Day 24:
From a call at 2:04 a.m. the crew began preparations for the scheduled trim burn to adjust the orbital groundtrack in preparation for the second mission in July. Ignition of the two RCS engines on the service module came at 3:59:27 a.m. for a 9 second burn with a ΔV of 0.3 fps. During the Stateside pass beginning 9:05 a.m. President Nixon spoke to Conrad through Mission Control and complimented him on the excellent performance of the crew. Later in the day, at 4:17 p.m., Conrad's family spoke to him for the second time on their 20th Wedding Anniversary. The entire family were present for the 8 minute pass. Later, conversation was held on the EVA scheduled for Day 26. During the day Weitz had played test subject to the LBNP, vectorcardiogram, ergometer, and vestibular chair, joined by Kerwin for the latter experiment. Some 5 hours 42 minutes ATM activity had also been accomplished. The astronaut manoeuvring chair, a device originally scheduled for test runs in the spacious OWS dome on Mission 1 but subsequently deleted, was checked out with activation of the reaction jets in the stowed configuration. The final goodnight from the ground came at 6:13 p.m.

Mission Day 25:
The crew were awakened at 2:02 a.m. and at 2:22 a.m. had passed the Russian long duration flight record of 23 days 18 hours 22 minutes set up by Soyuz 11. At 3:00 a.m. they requested that Mission Control relay their best wishes to the USSR and the cosmonauts. Much of the crew's afternoon hours were spent in EVA preparations and general discussion on the procedures. The 3 hour EVA was to begin at 6:40 a.m. The crew started their rest period at 6:01 p.m. Essentially all the experiments scheduled for Mission 1 were now completed, with 81% of the ATM work accomplished, 88% of EREP time run (with 60% of the data takes completed), 90% of the medical tests performed, 90% of the many corollary experiments completed, and 90% of the five student experiments carried also performed. Today the LBNP, ergometer and the vectorcardiogram had been run on Conrad and Kerwin, with the latter crewmember also wearing the sleep monitoring equipment this night. The beta angle (see Day 21) was increasing and now stood at 62.5°, affording only 20 minutes of darkness per orbit. Even so there was time for only 3 hours 51 minutes ATM activity.

Mission Day 26:
The crew were awake at 2:14 a.m. with immediate preparations for the EVA, scheduled to begin at 6:40 a.m. Rapidly completing the preparations and checkout, the crew began EVA at approximately 5:46 a.m., some 16 minutes before a 17 minute pass over the US tracking station. During this pass the TV was running to show the crew outside the airlock module and in the general direction of the fixed airlock shroud. Before loss of signal through the Bermuda station Conrad, with a heart rate of 130/min. had tapped on the compartment containing CBRM-15 and freed the stuck relay providing Skylab with another 200 watts power. Metabolic activity during the pass showed Conrad to be expending an average 1200 Btu. Before starting the film retrieval tasks Conrad advised Mission Control that the aft rod on the parasol mechanism failed to fully deploy and recommended rotating the shade some 15° counterclockwise. During the 41 minutes it took Skylab to move from the Bermuda station to the Carnarvon station Conrad cleaned the optics to the white light coronograph and then removed both its canister and those housed in the X-ray spectrographic telescope, the X-ray telescope, the H-alpha experiment, the X-ray ultraviolet coronal spectroheliograph and the ultraviolet spectrograph, bringing some 30,242 frames into the workshop for return to Earth. By 7:16 a.m. the station had been acquired at Guam with the news that Conrad had just finished deploying an 18 in.^{2} piece of parasol material from the A-frame sail so that half would be constantly in shadow and the remainder exposed to the rays from the Sun. Retrieval on Mission 2 would permit analysis of long term effects. At loss of signal some 13 minutes later Conrad was preparing to retrieve the thermal coatings experiment, the last task on this final EVA. By 7:29 a.m. the crew were pressurising the airlock module after completing a 1 hour 36 minute EVA. This activity had been scheduled to run for 3 hours but coupled with the early start the crew were now more than 2 hours ahead of time on the day's activities. During the EVA the crew reported on the apparent accumulation of shredded particles in the ATM canister mountings and the thermal degradation of insulation on the command module. Already the CSM had been in orbit for twice as long as any previous Apollo, and such determinations were important to the 2-month stays of the Mission 2 and 3 CSM's. For the rest of the day the crew were primarily concerned with activities that were scheduled for Day 27, taking advantage of the extra time to move up as many entry preparations as possible. At approximately 1:30 p.m. the parasol was swung counterclockwise in an attempt to bring down the few areas in the crew quarters that still showed high temperatures. At 4:15 p.m. the crew noticed that the sleep compartment temperatures were actually rising and swung the parasol back to more closely approximate the desired 15° rotation. By 5:00 p.m. the temperature sensors were showing a considerable reduction. The final communication with the crew terminated at 7:01 p.m.

To be continued]

A EUROPEAN SPACE AGENCY

A MAJOR STEP FORWARD

By Kenneth W. Gatland

Continued from March 1973 issue, page 118]

After 13 hours of intense debate at the European Space Conference which resumed in Brussels on 31 July, Aerospace Ministers from 11 European countries – including Britain, West Germany and France – agreed to create a European Space Agency by 1 April 1974 by merging ELDO and ESRO, and also to cooperate in America's post-Apollo programme by accepting the 4-man Space Lab as a European project. In addition the go-ahead was given for the French-backed L3S satellite launcher and the British-backed maritime satellite for improving ship-to-shore communications.

Thus the entire package of European future space projects, which only two weeks before had seemed likely to collapse, has been approved with only minor shifting of ground. An earlier Ministerial conference on 12 July had broken up after only three hours (see *Milestones*, September issue).

M. Charbonnel, the French Minister for Industrial and Scientific Development, had made no secret of his displeasure with Britain over her refusal to back the new £190 million L3S rocket which he claimed was essential to give Europe independence in launching satellites for communications and other commercial purposes. Germany and Belgium were reported ready to chip in 18% and 4% respectively. But the British Government had stubbornly refused to contribute on the grounds that this would be merely re-creating established US technology and Europe's satellites could be launched in the United States.

In the event, in order to pacify the French, Britain elected to contribute £4.7 million over 8 years towards the L3S with the proviso that Britain should be given responsibility for the inertial guidance package on a purely contractual basis. Britain therefore stays out of the L3S agreement and does not become involved in the projects costs.

Meanwhile, the National Aeronautics and Space Administration had set 15 August as the deadline for European acceptance of the £128 million Space Lab. West Germany backed Space Lab as staunchly as the French backed L3S but – like the French – sought contributions from others. Britain, in turn, was prepared to contribute to Space Lab if others supported her main interest – Maritime satellites. (The adopted project, Marots, incidentally, is based on the Orbital Test Satellite (OTS) studied under ESRO contract and not the British national Geo-stationary Technology Satellite (GTS) which has been dropped). As it turned out, the Italians, who have a firm interest in Space Lab, were unable to make an immediate commitment to any project because their new Government was making a review of all national expenditure. They were left to reach a decision by mid-September. In the meantime, it was agreed that the US Government should be notified of Europe's acceptance of Space Lab conditional upon Italy's agreement.

Financial Involvement

Currently Europe is spending over £190 million a year on non-military space activity, which is about one-sixth of the present US space budget. Under the new arrangements, which will gradually merge European national and international programmes, individual countries must agree among themselves which projects they wish to support; contributions are *not* related to Gross National Product. If there is insufficient backing for a given venture, it will be up to the proposer nation to increase support or let the project lapse.

To many people's surprise, the July-August Conference went a long way towards floating the total package without placing strains on Britain which still maintains a total civilian space spend of around £20 million a year. Percentage contributions worked out broadly as follows, with some uncertainties to be resolved later.

Contributors	L3S (£190 m)	Space Lab (£128 m)	Marots (£31 m)
	Percentage of Total costs*		
Germany	18.8	52.65	20.0
Belgium	5.0	4.2	1.0
Denmark	0.5	-	† Uncertain
Spain	2.0	2.8	† Uncertain
France	62.5	10.0	15.0
U.K.	2.65	6.3	56.0
Switzerland	1.15	1.05	-
Netherlands	1.00	2.00	-
† Italy	) assumes	) assumes	) assumes
† Norway	) total of 6.0	) total of 21.00	) total of 8.0
† Sweden	)	)	) with Spain and Denmark
Totals	99.9	100.00	100.00

* *Figures are provisional as agreed on 1 August.*

† *To decide by mid-September.*

Thus, Britain's contributions work out to £4.7 million over eight years for L3S; £8.1 million for Space Lab over eight years, and £17.5 million for Marots over six years. Although many will feel that these are relatively small sums for Britain to invest, particularly in Space Lab, one can gain satisfaction from the fact that European Governments are at last prepared to endorse coordinated space effort. It remains to be seen how effectively this can be carried out in practice. How realistic are the financial estimates for the major space projects L3S and Space Lab only time will tell.

A B.I.S. Statement

On the morning of 1 August the following statement was issued to Press Agencies on behalf of the B.I.S. Council:

'We congratulate Mr. Michael Heseltine on winning approval for a European Space Agency. This is entirely a British initiative, and was first proposed by the British Interplanetary Society in recommendations to the Wilson Government in 1965 but was never taken up. In recommendations to the present Government in February 1972, the Society urged:

'European initiative, with immediate action to strengthen European space management by merging ELDO and ESRO into a single European Space Authority. This body to be given full authority to negotiate terms for a viable international programme, initially with the National Aeronautics and Space Administration, within the context of the approved post-Apollo programme......'

'Acceptance of a European mini-NASA now promises great rewards for European industry. Long-standing neglect of central management in European space affairs had led to waste of limited resources and frustrated Europe's entry into potentially profitable markets. Within ESA, Europe now has a chance to work at the space frontier alongside the United States and to develop other space capabilities of enormous

social and economic importance. These include satellites for international communications (including ships and aircraft), navigation and air-traffic control, weather survey, Earth resources survey and pollution control.

'Within ESA, Europe will build a 4-man orbiting laboratory – Space Lab – which will be carried into orbit by America's revolutionary space-plane, the space shuttle, which takes off vertically like a rocket but returns to land on a runway with great saving in launching costs. In the 1980's it will give our scientists and engineers the opportunity to do original research under weightless conditions in orbit which could lead to important new industrial processes, and big advances in astronomy, medicine, biology and many other fields of human interest'.

The U.K. Government View

Before going to Brussels Mr. Heseltine had made a major policy statement during a speech at the annual dinner of the Society of British Aerospace Companies on 27 June. 'For a decade now', he said, 'we have had a European framework for space projects, our industry has grown used to multinational consortia which compete for new projects, and work across a broad range of technology. We have test facilities, control stations, and launch complexes. Yet.... what kind of coherent European achievement have we to show for it?

We cannot, of course, match the United States in terms of absolute expenditure. But we can within Europe seek to obtain more *value* for the money we spend. Has it really been worth Britain spending £250 m on national and international space programmes since the early 1960s? And if you cannot get good value in Europe for £190 m a year, which is what collectively the Europeans spend on civil space, is there any point in going on at that rate when our competitors spend six or seven times as much?

There are two features of Europe's space programmes which seem to me to provide the important clues to what may have gone wrong and might yet be put right. One is the lack of commitment to a strong central organisation; the other is the continued preoccupation with national advantage within the European framework.

Last year the combined budgets of ELDO and ESRO came to around £60 m; but in the same year the Member States of ELDO and ESRO spent about £130 m on civil space activities outside the European organisations, quite apart from their contributions to INTELSAT. Now there may be very good reasons why national or bilateral activities were undertaken outside the European framework, but whatever the reasons advanced it seems questionable whether a Europe which is ready to spend twice as much in separate national efforts as in a common European endeavour can be taken seriously as a single force in world space activities.

The fact is that the larger European countries – the UK certainly among them – have planned their national programmes not only to meet their home customers' requirements but also to give their industries a head start in bidding for high technology work from ESRO, in the hope of cornering a real commercial advantage in the longer term. The smaller countries, unable to take this route, have insisted in their turn on a strict application of the 'fair return' rule in ESRO contracts, to make sure that they keep for themselves an appropriate quantity of work. Instead of showing a common purpose we have seen Europe duplicating technologies and facilities in a range of unco-ordinated programmes. It is no wonder that our £190 m doesn't seem to go far.

Against this background the Ministerial conference in December agreed on the formation of a single European Space Agency to replace ELDO and ESRO, and to absorb progressively national civil programmes. Since then, officials and Ministers all over Europe have been examining the details of these ideas. We are to meet again in Brussels next month to try to reach agreement about the new Agency and its programmes.

I think two common pressures are persuading my European colleagues that the time for a change has come. The first is money. That will not surprise you. Governments are always short of that. The second is from the potential customers for applications satellites – the PTTs, for instance – who care far more for operating costs than for pushing forward the frontiers of European technology. But, even if everyone agrees at the forthcoming Space Conference that a new organisation with new objectives is needed, and that national activities should be phased into it, there may still be disagreements on which programmes the organisation should pursue. Launchers are the obvious example.

Here we and the French have held opposed views in recent years. The French believe it is essential for Europe to have an independent launch capability: hence their L3S design. We, on the other hand, think the risks of being refused a launch by the Americans are small and therefore acceptable, and do not justify our paying the premium of developing in Europe a technology which the US perfected many years ago. This is a serious difference of view, but one, I hope, which allows each side to respect the other's view while disagreeing with it.

My hope is that when we meet next month in Brussels it will be possible to approach the various programme options in this spirit. I can see no logical objection to having an integrated European space programme, including L3S, in which the individual projects are paid for according to the interest of Member States – and that may be a nil interest. We would not expect everyone to have the same interest in maritime satellites as we have, and accordingly we would be willing (as the French are on L3S, and the Germans on Spacelab) to pay a correspondingly larger share of the cost of such a project.

The new European Space Agency must be able to absorb these differences in national emphasis. It would of course be ideal if we all agreed on each programme, but we don't. Does this mean that we can make no progress in the areas where we do agree? This is possibly the single most difficult question facing the ESC next month.

My immediate task, at next month's Conference, will be to obtain agreement on the objectives of an industrial policy which will give the ESA a reasonable chance of achieving its aims. Europe needs the industrial strength to meet its future regional space requirements and to be a worthwhile partner in wider space systems. With that agreement must go a commitment by my European colleagues to be as ready as I am to accept the limits on national action which are necessary. Neither I nor they will be willing to begin to make the fundamental changes until we have that assurance from each other. No one can expect progress without compromise. It is my task as Minister to support the interests of British industry on its own until I see a wider opportunity for it in a larger grouping. Other Ministers will so support their own industries.... And Industry will have an important role to play.

EUROPE'S GEOSTATIONARY SATELLITE

British Aircraft Corporation, Electronic and Space Systems – on behalf of the STAR Consortium of European electronics and aerospace companies – has been awarded an £11 million contract by the European Space Research Organisation for the development and manufacture of Europe's first geostationary scientific satellite, GEOS. The three year development programme will involve 15 companies in 10 European Countries. In addition to certain satellite subsystems, BAC, as Prime Contractor, is co-ordinating design authority responsible for overall satellite system design and all aspects of the development programme.

GEOS will carry a payload of 9 scientific experiments (3 of which are integrated to form one unit) into geostationary orbit where from various positions in the magnetosphere the experiments will measure electric and magnetic fields and also particle densities and distributions. In addition the experiment data from GEOS will be correlated with ground based measurements.

As the first scientific geostationary satellite to be undertaken by European Industry, GEOS presents a number of technical challenges, e.g.

(1) Deployment of 8 booms in orbit ranging in length from 1.5 metres to 20 metres to isolate sensors from the satellite body;

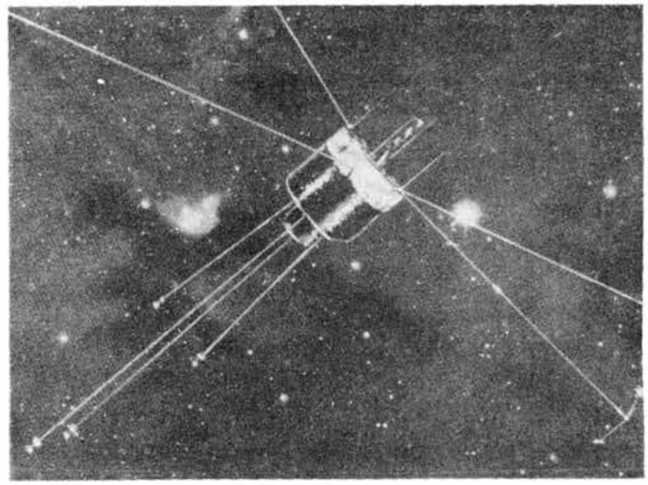
(2) Measurements by the experiments of much lower field intensities than on previous satellites which impose stringent limitations on the interference generated on board the satellite; and

(3) Severe limitations on contamination from the apogee motor and burnt hydrazine due to the sensitivity of the experiment sensors.

A European apogee motor will be specially developed for this programme, jointly by SNIA Viscosa of Italy and SEP of France.

GEOS Experiments

Research Institute:	Experiment:
Centre National d'Etudes des Telecommunications, France	Study of thermal plasma through its resonances
Group de Recherches Ionospheriques, France and Danish Space Research Institute, Denmark	Study of low frequency electromagnetic fields
ESTEC Space Science Division, Holland	Measurement of low frequency electric fields
Mullard Space Science Laboratory, London University.	Study of the very low energy plasma
Physikalisches Institut der Universitat Bern, Switzerland, Max Planck Institut fur Extraterrestrische Physik, Germany	Ion composition, energy spectra and angular distribution of low energy particles and plasma
Kiruna Geophysical Observatory, Sweden	Measurement of the pitch angle distribution of low energy electrons and protons
Max Planck Institut fur Aeronomie, Germany	Electron-proton spectrometer for medium energies
Max Planck Institut fur Extraterrestrische Physik, Germany	Measurement of DC electric field component perpendicular to the magnetic vector
Laboratory for Space Research, CNR, Italy	Measurement of DC and ULF magnetic fields



Artist's impression of the GEOS satellite as it will appear in geo-stationary orbit with eight booms deployed to isolate sensors from the structure and equipment. Launching is planned by a Delta rocket in 1976.

British Aircraft Corporation

GEOS DIGEST

Diameter:	162 cm.
Length:	110 cm.
Mass:	542 Kg. at launch
Power available:	90 watts
Spin rate:	10 r.p.m.
Orbit:	geostationary between 15° and 40°E.
Lifetime:	2 years
Launch:	Summer 1976
Vehicle:	Delta

The STAR Consortium team for GEOS and their main subsystems responsibilities are as follows:

Belgium:	
Etudes Techniques et Constructions Aerospatiales	Electrical ground support equipment
Denmark:	
Electronikcentralen	Power supply control Attitude and orbit control electronics
France:	
Thomson CSF	Telecommunications
Societe Europienne de Propulsion	Thrusters Apogee motor
Germany:	
AEG Telefunken	Solar panels
Dornier System	Structure Booms and mechanisms Attitude measurement
Italy:	
CGE Fiar	Power supply
Montedel Laben SpA	Data handling Electronic ground support equipment
Officine Galileo	Attitude sensors
SNIA Viscosa	Apogee motor

Netherlands:	
Fokker-VFW	Thermal Control Nutation dampers
Spain:	
Sener SA	Mechanical ground support equipment
Sweden:	
L. M. Ericsson	Antennae
Switzerland:	
Contraves AG	Structure
United Kingdom:	
British Aircraft Corporation	Project management System engineering Attitude and orbit control Wire harness Assembly, integration & test Launch support Electronic ground support equipment
U.S.A.	
Hughes Aircraft Company	Consultants

COOPERATION IN SPACE-MEDICINE

The USSR Academy of Sciences and NASA have approved the results of the third Joint Working Group meeting on space biology and medicine held in Moscow between 26 February and 6 March 1973. The Working Group exchanged information on experiences in manned space flight with special attention on preliminary biomedical results of the Apollo 17 mission and Soviet experimental research in the modelling of weightlessness.

Prior to this meeting the respective parties exchanged written information in the following areas with the objective of developing common procedures for pre- and post-flight examination of astronauts and cosmonauts:

(a) Evaluation of gas exchange and cardiovascular response to physical work;

(b) Evaluation of the cardiovascular system in response to lower body negative pressure and active orthostatic tests;

(c) Evaluation of vestibular function;

(d) Biochemical studies of blood and urine, and

(e) Fluid and electrolyte metabolism.

Discussion at this Third Meeting led to agreement of common testing procedures in the areas of lower body negative pressure testing, active orthostatic evaluation, and biochemical studies of blood and urine. These common procedures are to be implemented whenever these tests are utilized by either country. Common examination procedures will permit direct comparison of US and USSR pre- and post-flight data on selected body functional areas and thereby increase the information base of both parties regarding man's physiological response to space flight. In those areas in which agreements were not reached, the Working Group will exchange further written information and continue discussions at future meetings.

The Working Group also discussed, with prior exchange of written materials, countermeasures to be used in weightlessness and the results of biological experiments conducted in space. It was agreed that both of these areas will be pursued in future meetings.

During the meeting the US delegation visited several medical research facilities and the Gagarin Centre for Cosmonaut Training, Star Town, where the group examined spacecraft trainers, medical equipment used pre- and post-flight in the training and evaluation of cosmonauts, and medical instrumentation of the type utilised aboard the Salyut space station.

Co-chairmen of the meeting were Dr. N. N. Gurovskiy of the USSR Academy of Sciences and Dr. Charles A. Berry of NASA. The next meeting of the Working Group will be held in the US in late 1973 or early 1974.

ORBITAL FIREFIGHTER

Instruments developed to sense conditions when fires start easily are being teamed with a satellite relay station and computers to give the California Division of Forestry (CDF) a 'Fire Index Measurement' from an experimental unmanned remote station in a fire area near Sunol, California.

Foresters say that knowing where fires are probable and how they might act is almost as important as men and equipment actually fighting fires. An unmanned station to establish the fire index in remote areas is doubly important because it gives timely readings which have in the past been made by forestry personnel as only one of their many duties, and it has been a problem for them to get the information to their headquarters by telephone. Important, too, is the idea that when fires occur, forestry personnel are often pulled into firefighting duties and can no longer monitor their areas.

The system is based on sensors developed by the CDF and NASA's Ames Research Center, Mountain View, California, to check wind velocity and direction, air temperature, relative humidity, and fuel moisture content, a measure of the flammability of forest floor litter. Under an agreement between Ames and the Division Forestry, Ames aerospace technologists have joined the CDF instruments with a NASA 'black box' which converts their measurements into data which is beamed to the Earth Resources Technology Satellite (ERTS) at least twice a day.

The ERTS, orbiting Earth every 100 minutes, 915 km (540 miles) overhead, picks up the signals with special receiving equipment. The satellite automatically relays the information to a NASA tracking station in the Mojave Desert which passes it electronically to NASA's Goddard Space Flight Center in Maryland. The coded data is sorted out by computer and sent to Ames back in California where it is processed by computer and sent to Forestry headquarters in Sacramento, in a usable form. In the Sunol experiment, the fire index information is passed to Sacramento on a daily basis, but if need be it could be made available within an hour after an ERTS pass.

The success of the project is also sparking interest in the possibility of using the system to monitor air pollution. The fire index project is an example of a continuing programme at Ames to identify problems of public interest and concern and help local agencies find practical solutions through aerospace technology.

SATELLITE DIGEST — 63

A monthly listing of all known artificial satellites and spacecraft, compiled by Geoffrey Falworth. Information is based on that supplied by the Space Department of the Royal Aircraft Establishment, Farnborough, NASA, Satellite News and BIS sources. For information on the derivation of orbital parameters, abbreviations, etc., see July 1972 issue, page 262.

Continued from September issue, page 353.

Name, designation and catalogue number	Launch date, lifetime and descent date	Shape and weight (kg)	Size (m)	Perigee height (km)	Apogee height (km)	Orbital inclination (deg.)	Nodal period (min)	Launch centre, launch vehicle and payload/launch origin
Salyut 2	1973 Apr 3.38	Irregular cylinder +	12 long	207	248	51.56	88.99	Tyuratam-Baikonur
1973-17A	55.11 days	4 panels + antenna	4.15 dia	237	259	51.57	89.42	
				257	278	51.57	89.81	
6398	1973 May 28.49	18900		259	299	51.56	89.8	USSR/USSR (1)
Molniya 2E	1973 Apr 5.47	Cylinder-cone +	4.2 long?	477	39107	65.49	702.19	Plesetsk
1973-18A	5 years?	6 panels + 2 antennae	1.6 dia?	532	39827	65.24	717.73	
6418		1250?						USSR/USSR (2)
Pioneer 11	1973 Apr 6.09	Irregular hexagon +	0.97 long					ETR LC 36B
1973-19A	Infinite	hexagonal box +	2.74 dia		Heliocentric orbit			Atlas Centaur
		antenna + tripod +						
		3 booms						
6421		258.55						NASA/NASA (3)
Cosmos 553	1973 Apr 12.50	Ellipsoid	1.8 long?					Plesetsk
1973-20A	6 months		1.2 dia?	272	494	70.96	92.22	Cosmos
6427		400?						USSR/USSR
Cosmos 554	1973 Apr 19.38	Sphere-cylinder	5 long?	194	304	72.85	89.50	Plesetsk
1973-21A	38 days		2.44 dia	171	335	72.85	89.58	
6432	1973 May 27	4000?		171	380	72.85	90.04	USSR/USSR (4)
	1973 Apr 19.38	Sphere?						Plesetsk
1973-21E	12 days		2 dia?	169	359	72.85	89.80	
6443	1973 May 1							USSR/USSR (5)
Intercosmos 9	1973 Apr 19.43	Ellipsoid	1.8 long?					Kapustin Yar
1973-22A	8 months		1.2 dia?	199	1526	48.42	102.12	Cosmos
6433		400?						USSR/USSR (6)
Telesat 2	1973 Apr 20.98	Cylinder + antenna	1.52 long	35822	36508	0.4	1455.5	ETR LC 17B
1973-23A	10^6 years		1.88 dia	35781	35788	0.1	1436.0	Delta
6437		294.84						Telesat Canada/NASA(7)
Cosmos 555	1973 Apr 25.45	Sphere-cylinder	5 long?					Plesetsk
1973-24A	11.9 days (R)		2.44 dia	216	233	81.33	89.02	
6440	1973 May 7.3	4000?						USSR/USSR (8)
	1973 Apr 25.45	Sphere?						Plesetsk
1973-24D	14.39 days		2 dia?	209	222	81.33	88.84	
6444	1973 May 6.84							USSR/USSR (9)

Supplementary Notes:

(1) Second Soviet orbital scientific station further tested onboard systems and equipment in support of scientific and technical space research, flight tested onboard scientific and engineering systems, performed scientific research and experimentation, developed structural and mechanical systems for scientific and technical research and experimentation and further flight tested space station systems. Initial telemetry received by Soviet ground stations after launch indicated that all onboard systems were operating normally. On 1973 Apr 30 Soviets announced that Salyut 2's flight programme had been completed and that experiment data acquired during the mission confirmed structural and design correctness, subsystem and main system operations and onboard equipment functions, while mission data would be utilised in support of new spacecraft fabrication. Orbital data at 1973 Apr 4.0, Apr 5.7, Apr 8.6 and Apr 11.0.

(2) 28th communications satellite in Orbita network. Orbital data at 1973 Apr 18.2 and Apr 18.7.

(3) Pioneer G, eighth Pioneer spacecraft in heliocentric orbit and second Jupiter flyby mission acquires interplanetary data at increasing solar distances and acquires scientific data during close approach

to Jupiter. Onboard instrumentation and systems are similar to those on board Pioneer 10 (1972-12A) (see *Spaceflight*, **14**, 345, 1972). According to current trajectory estimates Pioneer 11 will flyby Jupiter over a point below the Jovian equator at 1974 Dec 5.19.
(4) Transmitted at 19.990 MHz.

(5) Ejected from 1973-21A during 1973 Apr 26.
(6) 11th Soviet co-operative satellite in which research institutions and observatories in Bulgaria, Czechoslovakia, German Democratic Republic, Hungary, Poland, Rumania and the Soviet Union provide equipment and observations of the satellite, studies solar radiation and its effects on Earth's ionosphere, Earth's upper atmospheric composition and ionospheric changes and charged electron and ion concentrations at orbital altitudes. Onboard instrumentation, supplied by institutions in Poland and the Soviet Union, measures solar radio flux in wide frequency ranges between 6 and 0.6 MHz for correlation with solar and ionospheric data acquired at Earth observatories, Intercosmos 9's orbital plane is aligned with apogee towards the Earth-Sun line to support spacecraft studies of radio frequency radiation effects on Earth's upper atmosphere. Preliminary telemetry utilising a Czechoslovak telemetry transmitter permitting ground stations in Czechoslovakia to acquire Intercosmos 9 real-time data telemetry indicated that all onboard instrumentation is operating nominally.
(7) Telesat B, second in a series of Canadian domestic communications satellites designed to act as a spaceborne communications repeater capable of receiving transmissions from Earth stations for retransmission to Canadian Earth stations provides an interim operational Canadian satellite communications capability, distributes network TV to major southern Canadian centres for further distribution by ground-based systems and to remote Canadian centres for local rebroadcasting, heavy-route message traffic between large population centres to supplement existing terrestrial systems and small group message services between northern Canadian centres and between northern and southern centres. Onboard instrumentation and systems are similar to those on board Telesat 1 (1972-90A) (See *Spaceflight*, **15**, 192, 1973). Telesat 2 also acts as backup satellite communications link to Telesat 1 from its internationally-approved and co-ordinated equatorial geostationary orbital location at longitude 114° West. Orbital data at 1973 May 1.0 and Jun 1.0.
(8) Transmitted at 19.995 MHz.
(9) Ejected from 1973-24A during 1973 May 4.

Decays:
1973-14A decayed 1973 May 19, lifetime 71 days (R).

Amendments:
Salyut 1 (1971-32A) size is 12 long, 4.15 dia.
1972-101A perigee is 31012, apogee is 20728, inclination is 9.7, period is 1440.4.
1973-13A catalogue number is 6380.
1973-14A catalogue number is 6382.
Cosmos 552 (1973-16A) lifetime is 11.76 days (R), descent date is 1973 Apr 3.18.

OBITUARIES

Dr. PAUL GAST – One of the most notable lunar scientists of our time, Dr. Paul W. Gast, died in a Houston, Texas, hospital on Wednesday 16 May. He was 42. For the past 3 years Dr. Gast had held the reins of lunar exploration as performed in the Apollo Programme, serving the Johnson Space Center as Chief of the Earth and Planetary Sciences Division. He played an instrumental part in planning landing site explorations and became a vibrant personality at JSC with the forthright and alert attentiveness he gave to minor problems and major crises alike.

Paul had always been a protagonist of manned lunar exploration and expressed discontent over the withdrawal of NASA interest from the Moon. He would often speak at length of the planning he knew would be necessary to expand on the limited knowledge acquired by Apollo, continually urging a rationale for return to active expeditionary flights. At the splashdown of Apollo 17 he confided: 'I feel at this point rather sorry that the explorations are at an end. I just hope that it won't be too long before we have a reasonable chance to explore the Moon further and, one would hope, to bring back some material from Mars as well'.

To those of us who had cause to consult his office on frequent occasions, and in pursuit of our own research, his influence was at once apparent. Paul was very eager to discuss the dissemination of original material and constantly exerted effort, beyond that required by his position, to bring before science the very best that NASA resources could offer. Many can never forget how thrilled he was to introduce Prof. Vinogradov to participants of the 2nd Lunar Science Conference on the afternoon of 14 January 1971. This spirit of international rapport would characterise his efforts throughout the remaining two years of his work. His vigorous and ebullient approach has left its mark on the efforts of so many of his colleagues.

With a B.Sc. in chemistry from Wheaton, Illinois, and an MA and Ph.D from Columbia, he joined the Johnson Space Center in January 1970, at once taking pains to link the technological genius of NASA with the demanding requirements of the scientific community. A personal friend and colleague, Dr. Strangeway, Chief of the Geophysics Branch, reflects: 'He was a creative scientist, able to publish many good papers about the Moon. There is no doubt that his dynamic leadership played a major role in the scientific success of Apollo'.

Faced with the knowledge that he had fallen victim to a fatal illness two years ago Paul carried on undaunted and was actively engaged in organising the 4th Lunar Science Conference last March. Few around him knew of the burden he bore and no greater tribute can be expressed than that present in the words of John Solomon: 'Achievement in the face of adversity is an achievement of a man over his mind. Prominence as a product of such achievement is the prominence of a man among men'. Few will contest that Paul W. Gast was a veritable giant among his peers.

DAVID BAKER

We also greatly regret to record the deaths of the following members:-

Dr. ALFRED FARAU (Fellow), a psychoanalysist practising in New York, U.S.A. at the age of 69 years.
LEONARD ERNEST GEARY (Senior Member), Engineer, at the age of 57 years.
VJEKOSLAV GRADECAK (Fellow), an Engineering Officer for the Public Works Department, New South Wales, Australia, at the age of 48 years.
SYLVANUS LLOYD MAUNDER (Senior Member), Director of a Food Refrigeration Company, at the age of 74 years.

RETURN TO WALLOPS ISLAND

By Tim Furniss

Introduction

Every Monday, Wednesday and Friday, solid propellent single-stage rockets complete one-minute countdowns and zoom into the sky over Wallops Island, Virginia. These launches are just three regular events that occur during a hectic week at this NASA facility that has grown in stature over the past 10 years to become a very important part of the United States' civilian aeronautical and space industry.

Those three rockets conduct meteorological research, just one of the many areas of activity. Research programmes in aeronautics, the project management of NASA-sponsored ballistic and orbital space programmes, the responsibility for part of the U.S. National Sounding Rocket Programme, the development of components and systems for the aerospace industry and the running of a regional ecological remote sensing programme; all come under the spectrum of activities at Wallops.

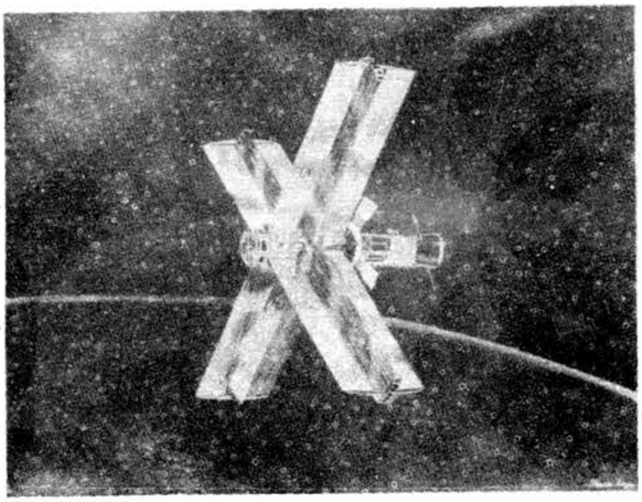
One of the busiest rocket launching centres in the world, NASA's Wallops Station is situated on the Eastern shore of Virginia some 50 miles south of Salisbury in Maryland. It consists of three areas – the main base, which belonged to the Navy until 1959, Wallops Island itself, from where the rockets are launched, and the Wallops mainland, where long range radars, optical tracking sites and transmitter facilities are located.

Wallops Island, which takes its name from the 17th Century surveyor John Wallop, entered the aerospace business in 1945 when the National Advisory Committee on Aeronautics (NACA) Langley Research Centre established a launch site on the island. Designated the Pilotless Aircraft Research Station, Wallops' early mission was to supplement wind tunnel and laboratory investigations into the problems of flight. The first launch from the site was of a 17-ft. Tiamat rocket on 4 July 1945. The station became a separate entity in 1958 upon the formation of the National Aeronautics and Space Administration (NASA) from NACA.

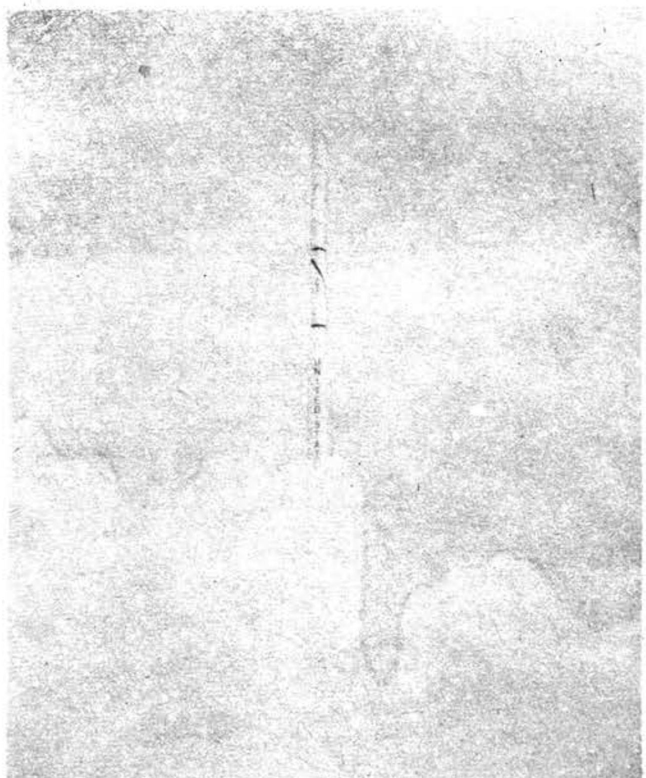
Since 1945, over 7,000 research vehicles, consisting of from one to seven stages, have been launched to provide information on the flight characteristics of aircraft, launch vehicles and spacecraft and to study the upper atmosphere. In the early years, research was concentrated on obtaining aerodynamic data at transonic and low supersonic speeds. More recently it has directly supported the manned space flight programme with the early testing, using Little Joe rockets, of various systems on the Mercury one-man spacecraft. Currently its mission is 'to obtain scientific data about the atmosphere and the space environment that can be devoted to peaceful purposes for the benefit of all mankind'. The information obtained by the station is freely distributed to the world scientific community.

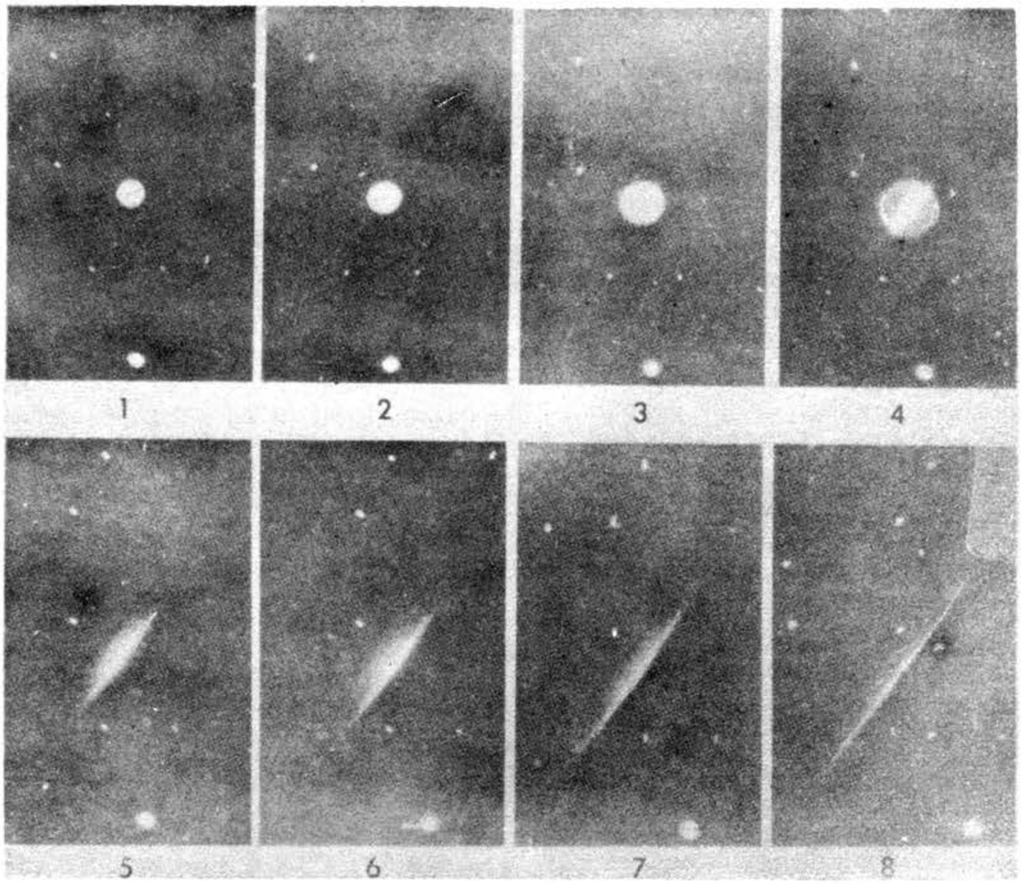
Wallops is probably the only launch facility in the world which is wholly under civilian control. When military boosters have been launched or military payloads have been boosted by civilian rockets the project and aim has been purely scientific. The fact that activities are entirely non-military means that there is less 'red tape' that exists at other bases. Also, having an airfield to themselves, Wallops' engineers are able to conduct hours of uninterrupted test flights without interference from other aircraft.

The 450 employees and 200 to 300 contractors' employees at the base are responsible to Robert L. Krieger, who arrived at the facility in that capacity in 1948.



Above, Artist's impression of the 175 kg Meteoroid Technology Satellite (Explorer 46) launched by a Scout rocket from Wallops Island on 13 August 1972. Object of the experiment was to collect data on the near-Earth meteoroid environment and its effect on spacecraft structures.
Below, the Meteoroid Technology Satellite ascends from the launch pad to achieve an orbit ranging from 492 to 811 km inclined at 37.7° to the equator.





Barium ion cloud experiment. A NASA Scout rocket bearing a German-built payload was launched from Wallops Island on 20 September 1971. Three hours and 34 minutes later, at 20,000 miles (32 190 km) altitude, the barium was released by a timing device forming a cloud above Central America. Within a minute or so of exposure to the Sun's UV radiation, the barium atoms became ionized (see pictures 3 and 4) showing white streak through cloud). Once ionized, the individual electrically charged particles were drawn down the Earth's magnetic field lines (pictures 5, 6 and 7) in tight spiral paths causing the ion cloud to become longer with time, thus visibly tracing the magnetic lines of force in space.

National Aeronautics and Space Administration

Aeronautical Research

Aeronautical research at Wallops has reached a peak this year and now that the space programme is being phased down more emphasis is being placed on this project area. While the overall aerospace budget of NASA has been trimmed, the aeronautical research department has been given a 200% budget boost.

Experiments to obtain aerodynamic and flight characteristics of all types of vehicles have been made using rockets such as the Scout which has enabled re-entry vehicles to reach speeds of 39,000 ft/sec. in studies of Apollo re-entry capabilities.

In July 1972 NASA launched a Trailblazer II re-entry vehicle to study the feasibilities of eliminating the radio blackout during re-entry using chemical injection. The payload, lofted to a height of 200 miles from Wallops, had a chemical injected into the plasma surrounding the vehicle during re-entry. The measurements included RF signal attenuation, antenna coupling measurements on an S-band transmitter and plasma electron density measurements by electrostatic probes.

Aircraft flight testing programmes at Wallops are co-ordinated be Gene Goodwin and are flown by NASA pilots. Wallops is also used to support the NASA Langley and Ames centres whose programmes are somewhat restricted by the fact that they share bases with the USAF.

Flight studies are made of steep approach and landing systems procedures, noise abatement, boundary layer control, vertical and short take-off and landing flight vehicles, helicopter stabilisation, terminal area navigation and collision avoidance systems. The airport, which includes two 9000 ft. long runways, has been modified to study the effect of runway grooves as a means of controlling aircraft hydroplaning on wet or slush-covered runways. Studies of automotive hydroplaning have also been conducted using the runways.

The following are examples of current programmes:

1. *VTOL 'Real World' Cue Display Programme.* (a) Flights to document the electro-optical parameters for the 'real world' CRT-type display, such as magnification, field of view, resolution, aspect ratio, contrast, pilot's subtended viewing

angle of the monitor and colour. (b) Flight test using the total system capability involving the integration of 'real world' and abstract cues.

2. *STOL Crosswind Landing Study.* (a) Determine the relationship between aircraft control, aircraft response, piloting technique, flight safety margins and crosswind limits during STOL operations. (b) Design and evaluate a crosswing landing gear.

Gene Goodwin, Project Co-ordinator, Aeronautical Programme Branch, NASA, elaborated a little on this programme. 'The STOL', he said, 'is still an unwanted child. The ATC boys have no time for it. It is slow. It takes off slow and lands slow'. The inference is that the STOL messes up the busy schedules for landing and take-off. Goodwin said that consequently the STOL is being assigned to secondary runways at airports where they can't interfere too much. Irrespective of weather conditions they are expected to land. This is the basic reason for the crosswind landing study.

3. *STOL/ATC Programme.* (a) Development for STOL aircraft of flight director capability for curved and segmented localiser approaches. (b) Validation of simulation studies conducted in joint NASA/FAA STOL/ATC programme.

4. *CH-46C Handling Qualities Investigation.* (a) Perform automatic approaches including intercept, deceleration to hover along descending flight path, and vertical descent to touchdown on the helicopter pad.

5. *Zero Visibility CTOL Operations.* (a) Eventual objective of the programme is for a CTOL aircraft to land safely in zero visibility using cockpit instrumentation only. (b) Initially, define flight paths for descending, turning approaches to the landing system interface.

6. *Microwave Landing System.* A phase two feasibility study is being undertaken to conduct flight tests for two separate groups of contractors who will be using two different systems each for a nine month period.

Goodwin also announced the arrival at Wallops of the Kestrel for Terminal Area Navigation tests. These were to be conducted with variable nozzle settings from 0° to 80° at speeds between 70 to 160 knots at heights between 500 and 1000 ft.

Table 1. Examples of Chesapeake Bay Ecological Remote Sensing Programme Experiments.

Study of the Eastern shore agriculture for the Virginia Polytechnic Institute and State University.

Pine beetle control programme conducted by the Virginia Division of Forestry.

Pine beetle detection being carried out by the Delaware Pine Beetle Control Council.

Virginia wetlands indentification required for the Virginia Institute of Marine Science.

Ecology of the Rhose river watershed for the Smithsonian Institution.

Table 2. Launch Areas at Wallops Island

Launch Area 0
Javelin, Astrobee and Trailblazer 2 rockets are launched from a tabular launcher enclosed in a shelter.
A HAD-1 launcher is used to handle Nike Apache. Nike Cajun and Nike Tomahawk rockets.

Launch Area 1
This consists of a 160 ft. tall tower – 80 ft. inside the building and 80 ft. above the roof line – from which the only liquid fuelled rockets – Aerobee 150A and 350 – to be launched at Wallops begin their journeys.

Launch Area 2
Probably the busiest site, Area 2 contains many launchers capable of handling Nike Cajuns, Nike Tomahawk, Arcus, Hasp and other rockets. It was the site of the first rocket launch to be made from Wallops on 4 July 1945.

Launch Area 3
Here the only orbital rocket – the Scout – is launched. On other launchers within the Area are for various two stage Nike combinations.

Launch Areas 4 and 5
From the different types of launcher erected here are boosted Nike Ajax, Trailblazer and RAM rockets.

Table 3. Major Launches from Wallops Island during 1972.

3 Feb. A two-stage Terrier Recruit was launched to study nose cone rain erosion.
6 Feb. A Nike Iroquois was launched for the USAF Cambridge Research Laboratory with a negative ion mass spectrometer experiment.
10 Feb. A Javelin rocket failed to launch a Goddard SFC and NOAA energetic particles and fields experiment.
17 Feb. A Terrier Recruit repeated the rain erosion on nose cone test.
29 Feb. A single stage Nike was launched for Langley Research Center on a solid-propellent dynamic study flight.
9 Mar. Nike Tomahawk was launched with an energetic particles and field experiment for the University of New Hampshire.
15 Mar. First of 29 meteorological sounding rockets was launched for the UN Commission for Instruments and Methods Observation of the World Meteorological Organisation. The launches ended on **21 March** and included US, Japanese and French experiments using US and Japanese rockets. These included, the Loki, Datsonde, MT-135 and Super Arcus.
17 Mar. Terrier Recruit was launched on nose cone rain erosion test.
22 Mar. As 17 March.
25 Mar. Nike Javelin launched a caesium plasma cloud geomagnetic perturbation experiment for the Naval Research Laboratory.
27 Mar. As 25 March.
29 Mar. As 25 March.
3 Apr. The fourth and fifth NRL launches.
13 Aug. Explorer 46 – MTS – launched by Scout.
16 Aug. Final Terrier Recruit launched in clear air envrionment for correlation of data from previous rain erosion tests.

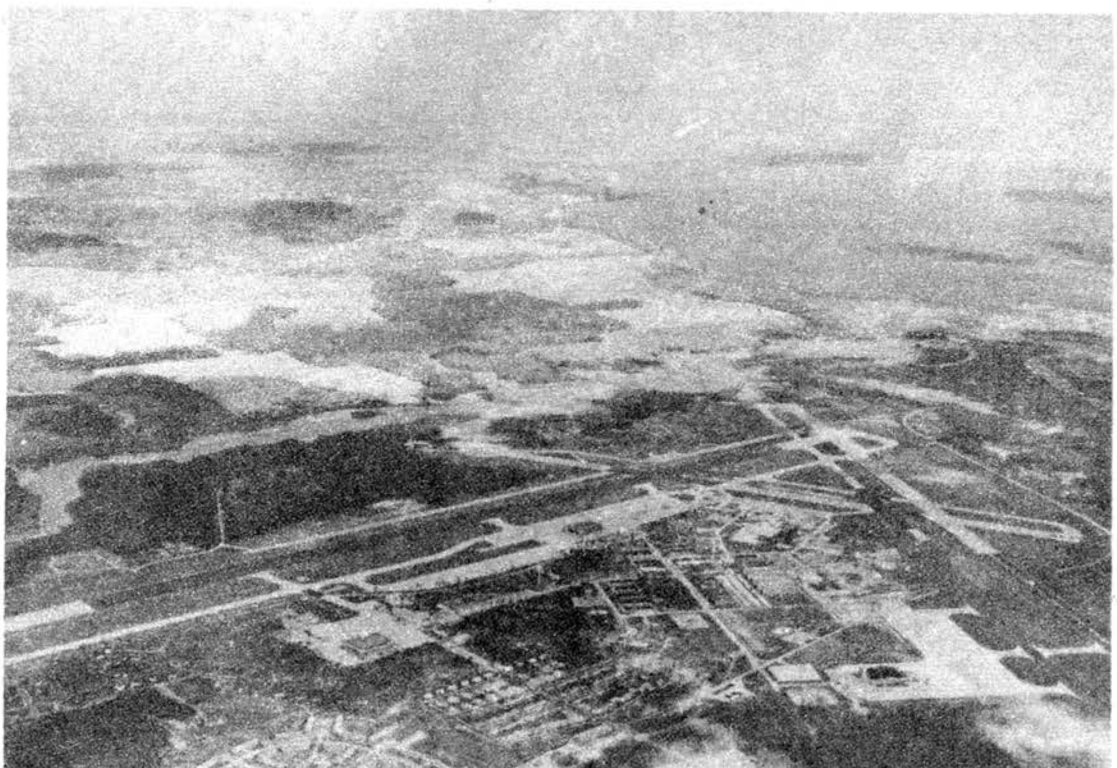
Table 4. Satellite Launchings from Wallops Island*

Explorer 9 - 16/2/61
Explorer 13 - 25/8/61
Explorer 16 - 16/11/62
USAF scientific satellite - 28/6/63
Ariel 2 - 27/3/64
Explorer 23 - 6/11/64
San Marco 1 - 15/12/64
Explorer 27 - 29/4/65
Secor - 10/8/65
Explorer 30 - 18/11/65
OV3-4 - 10/6/66
Explorer 27 - 5/3/68
Orbiting Frog Otolith satellite – and piggy-back radiation and meteoroid detection satellite - 9/11/70
Explorer 44 - 8/7/70
EOLE - 16/8/71
Explorer 46 (MTS) - 13/8/72

* *All employed the four-stage Scout.*

All illustrations National Aeronautics and Space Administration

Above, aerial view of Wallops Station showing the airfield, administration buildings, laboratories and workshops.
Below, launch pads along the coast.



Project Management of NASA-sponsored Projects

These projects do not just include orbital flights but many sub-orbital ones. Wallops is also organising the operation of remote launching and tracking facilities. NASA sponsors laboratory and research centres within the agency, other government agencies, colleges and universities and the worldwide scientific community. These agencies submit their projects to a NASA board for approval. The board then decides its scientific merit before assigning it a rocket and the launch facilities. Also, overseas agencies come to Wallops to have their satellites launched and also learn how to establish their own sites and launch American rockets as was the case with the Italians and their San Marco launch site off-shore of Kenya.

Some 62 countries have sent representatives to Wallops to observe its operations or seek assistance of some kind.

Examples of such projects are:

(1) A four-stage, 48 ft. long Javelin rocket lofted a 130 lb. probe to a height of 529 miles on 10 February 1972 for the Goddard Space Flight Centre and the National Oceanic and Atmospheric Administration (NOAA). The instruments measured the composition and concentrations of upper atmosphere ions and solar wind neutral hydrogen atoms.

(2) A series of cesium cloud experiments was carried out during March and April of last year for the Naval Research Laboratory (NRL). NRL scientists conducted a variety of radio propagation, photographic and geomagnetic observations from rocket-released clouds of caesium ions some 60 miles up. The rockets used were Nike Javelins.

(3) In September 1971, a Scout rocket bearing a German-built payload was launched from Wallops Island to a height of 20,000 miles. The payload – built by the Max-Planck Institute – released a barium cloud in space. This was observed from the North and South America's and the western-most parts of Europe. Because weather conditions had to be perfect at each of the observation posts the launch was held over night after night. The cloud was visible to the naked eye as a 'star' almost as bright as alpha Ursa Minor – the Pole Star. Within a minute or so of the release of the neutral barium cloud, the Sun's ultraviolet radiation ionised the atoms of barium, i.e. stripped each one of an electron. Once ionised, the individual electrically-charged particles were drawn down the Earth's magnetic field lines in tight spiral paths causing the ion cloud to elongate, thus visibly tracing magnetic lines of force in space.

(4) Explorer 46 was launched for the Langley Research Centre from Wallops Island by a Scout rocket on 13 August last year. Called the MTS – the 17th satellite to be launched from Wallops – it gathered information of the meteoroid environment in space.

(5) A French meteorological satellite, EOLE, ascended from Wallops Island on 16 August 1971. The satellite, developed by the Centre National d'Etudes Spatiales (CNES), was a co-operative venture with NASA.

Wallops performs many rocket launches as part of the Experimental Inter-American Meteorological Rocket Network (EXAMETNET). These launches, which are conducted every Monday, Wednesday and Friday of every week, are made using Arcus, Hasp and Loki rockets. These are single stagers and have very short burn times and high acceleration. The meteorological payloads they boost to various heights in the atmosphere are parachuted back to Earth. Arcus – the largest used – has a burn time of 30 seconds and burnout occurs at 60,000 ft; the payload apogee is 190,000 ft. Loki, on the other hand, has a burn time of only two seconds. In this time it can boost payloads to 7500 ft. after which they continue to about 11,000 ft. before falling back to Earth.

Now, for the first time, the Wallops facility has project management responsibility for a satellite which is to be launched elsewhere. This is the GOC geodetic satellite, due to ascend from the Western Test Range later this year.

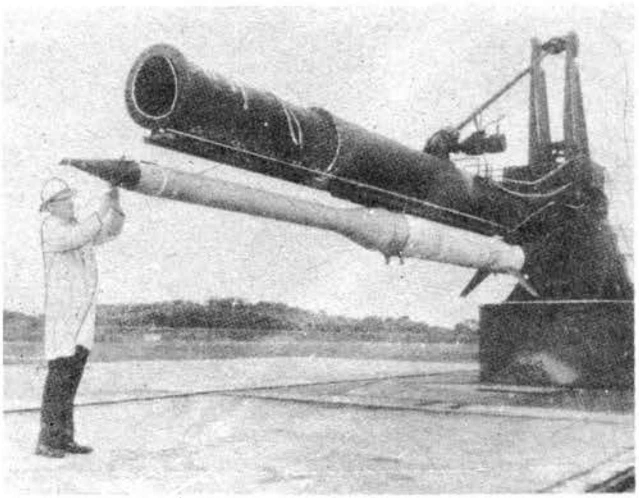
Sounding Rocket Programme

NASA's Wallops station also has management responsibility for the agency's portable range facilities for sounding rockets, including a rocket site at Point Barrow, Alaska. The centre is responsible for a third of the nation's National Sounding Rocket Programme. This requires programme interface with scientific, educational and international communities. Engineering support is furnished by Wallops and includes analytical, feasibility and design studies, payload, vehicle and recovery systems engineering. test and evaluation, and data analysis and reporting.

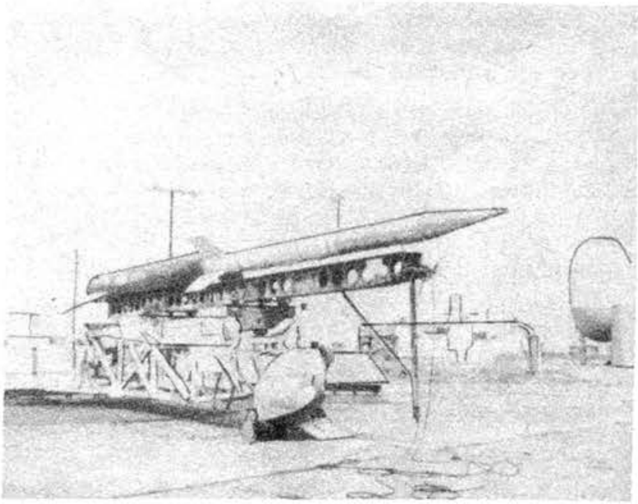
Sounding rockets are usually used to fill the data gap between balloon level – about 20 miles – and satellite altitude. Experiments flown by Wallops Station provide a variety of information, including high altitude wind shear and velocity, density and temperature of particles in the upper atmosphere, properties and changes in the ionosphere and measurements of the brightness of stars and radiation from the Earth.

Components and Systems Development

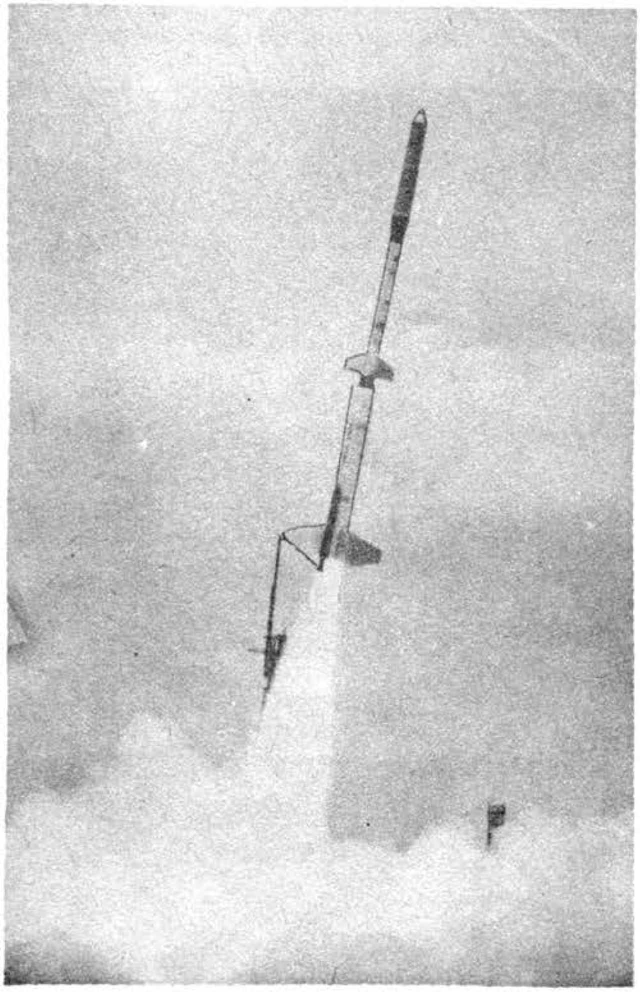
Many of the experiments conducted fall in the category of basic testing and development of components, systems, subsystems and instrumentation to be flown in later types of vehicles and spacecraft. Some past examples were related to Project Mercury, the Echo balloon satellite, Orbiting Astronomical Observatory (OAO), Canadian Topside Sounder satellite, and studies the Apollo command module's heatshield material. Recently some expeiiments for the Skylab programme were being studied.



A Terrier-Recruit rocket being prepared for a rain-erosion test.



Above, Nike-Javelin III on the adjustable launcher.
Below, a two-stage Trailblazer assisted by twin boosters blasts off from Launch Area 4.



Chesapeake Bay Ecological Programme

Ecological remote sensing began in a small way at Wallops during the 60's. By 1970 it had developed into a special programme managed by NASA. The Chesapeake Bay area is an entity in itself, including, on a small scale, all the ecological phenomena being studied throughout the US and the world. The area is unique in that a very large number of local state and federal agencies were already studying the area and this provided the impetus which formed the NASA-managed programme. The Chesapeake Bay area is now being studied from a U-2 and other aircraft based at Wallops. At the same time, relevant ERTS photographs are being supplied to the NASA station. About 330 hours of Wallops aircraft time during the 1972-73 will be utilised in the ecological project.

NASA says that the objectives of the programme are: 'to continue the devlopment of Chesapeake Bay region in an area where many practical applications of remote sensing from aircraft and spacecraft can be identified, demonstrated and evaluated, and to provide low-altitude remote sensing underflight for ERTS 1 investigators in the area.

The scheduling activities is a strong function of the weather and the dynamics of the Bay parameters being detected, monitored or measured. Sensors utilised are primarily multi-band cameras and thermal radiometers. Colour IR photography is extensively used. A small data bank at Wallops provides data storage, retrieval and dissemination capability as well as viewing and analysis work areas and equipment for investigators.

A Look Around Wallops

As you drive the seven miles from the main base to the Wallops mainland, you enter a very rural neighbourhood of houses with typical southern confederate architecture. A graveyard holds remains dating back to 1600. A farm – Wallops nursery – operates less than three miles from the launch site. The owner's plane is the only non-NASA vehicle allowed to land at the main base airfield. After passing through the town Atlantic, you pass the farm and turn left into the mainland radar area and continue towards the causeway connecting the mainland to the island. The island consists of five launch areas with 25 launch pads, towers, pedestals and booms.

On the main land radar area is situated a long range radar parabolic 60 ft. diameter SPANDAR antenna which is erected on a 80 ft. high tower. This Space Range Radar tracks and obtains data from experiments launched from the island, and is used for other satellite tracking. It has a transmitting power of 7 million watts and can track an experiment from 5000 miles with an accuracy of plus or minus 10 yards. Also on the site are a radar research facility, optical tracking buildings, and an FPQ-6 radar system, the latest development in long-range high precision radar. It has a range capability of 32,000 miles.

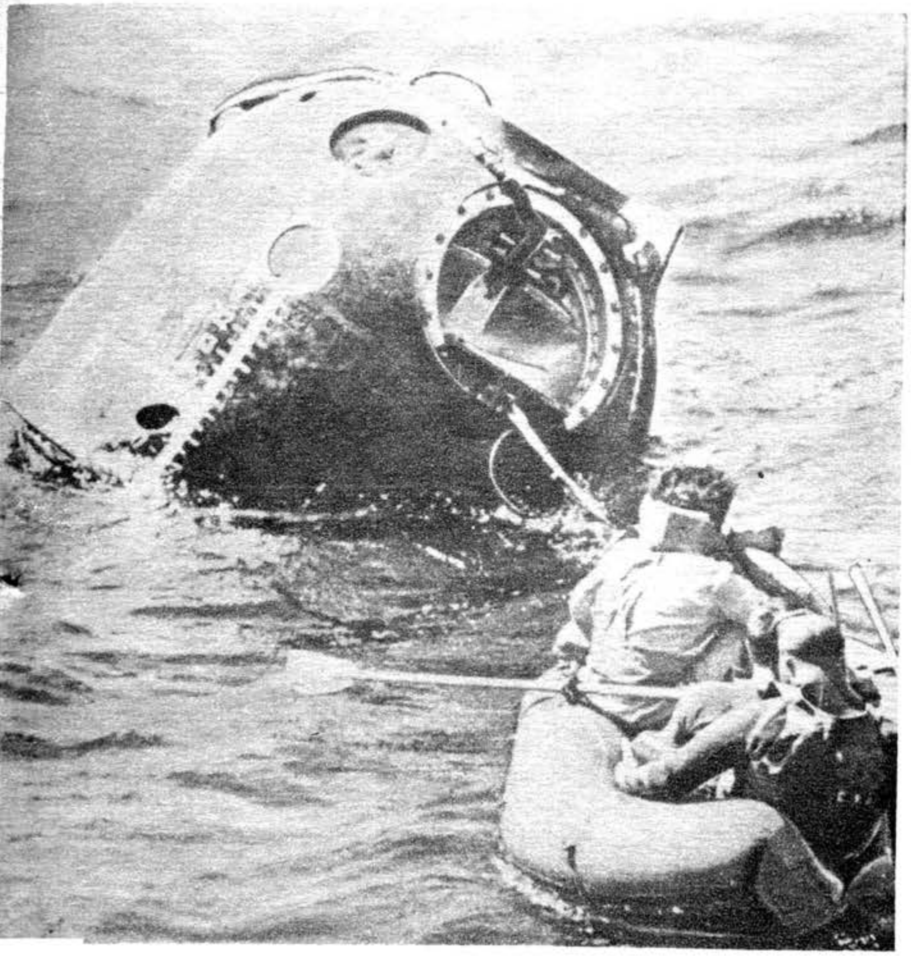
Launch sites apart, the island launch area includes a meteorological observation centre, island radar site, old dock area (prior to 1960, when the causeway was erected at a cost of 1½ million dollars, all equipment and personel reached the island by boat) a liquid storage area, lagoon sewage system, a Doppler Velocity and Position ground station, assembly shops, 250 ft. and 315 ft. high meteorological towers, blockhouses, a technical service shop, old administrative building and a cafeteria.

The island is protected from the marine environment by a sea-wall which had to be rebuilt after a severe storm in March 1962. Sea erosion is a great problem. Those who think that the sea is near the pads at Cape Kennedy ought to see how close the sea comes to the pads at Wallops Island.

SPACEFLIGHT

Внеочередной 88905 КОСМИЧЕСКИЕ ПОЛЕТЫ № Т-11
(спейсфлайт)
По подписке 1973 г.

Volume 15 No. 11 November 1973



Published by The British Interplanetary Society

ВНИМАНИЮ ПОДПИСЧИКОВ!

В связи с задержкой поступления из-за журнала "Комические полеты" № IO инд.88905 посылаем Вам последующие номера.

Editor:
Kenneth W. Gatland, FRAS, FBIS

Assistant Editor:
L. J. Carter, ACIS, FBIS

CONTENTS

COVER

SOVIET COSMONAUTS RESUME SPACE TRAINING. As part of the extensive training programme for the U.S. – Soviet joint docking experiment in 1975, Soyuz cosmonauts have been rehearsing procedures for rescue at sea. Normally Soyuz capsules parachute back to Soviet territory using solid retro-rockets to cushion the touchdown within one metre of the ground. The same procedure will be followed in the ASTP experiment except in an emergency. *Top left,* prime crew members Alexei Leonov and Valeri Kubasov leave the Soyuz capsule in an inflatable dingy during a practice session in the Black Sea. *Right,* Leonov and Kubasov in pressure suits which will be worn during ascent and re-entry. *Bottom,* Leonov (left) and Kubasov during medical tests at the Gagarin Space Research Centre. A progress report on the Apollo-Soyuz Test Project (ASTP) appeared in *Spaceflight,* September 1973, pp. 341-343.

Novosti Press Agency

SPACEFLIGHT

A Publication of The British Interplanetary Society

VOLUME 15 NO 11 NOVEMBER 1973 *Published 15 October 1973*

MILESTONES

July

30 Mid-course correction made to trajectory of Mars 4.

August

1 Martin X-24B lifting body with NASA pilot John Manke makes first flight, unpowered, from B-52 at 40,000 ft landing after 4 min 11.5 sec at Edwards Air Force Base, California.

3 Mid-course correction made to trajectory of Mars 5.

4 Team of JPL radio-astronomers under Dr. Richard Goldstein announces that radio sounding of an area of the equator of Venus in June 1972 found large shallow craters, one about 100 miles (161 km) across and less than 0.25 mile (0.40 km) deep.

5 Soviets launch Mars 6 spacecraft by Proton rocket from Baikonur cosmodrome 'for the exploration of Mars and surrounding space'. Design 'differs somewhat' from that of spacecraft launched in July; Mars 6 will carry out part of its scientific programme in conjunction with equipment on Mars 4. Craft also carries French Stereo experiment for observing simultaneously from Earth and space radio bursts from the Sun in the metre band; also instruments for measuring solar plasma and cosmic rays.

6 Skylab astronauts spacewalk for record 6 hr 31 min to fix new sunshield, replace film canisters in ATM and inspect damage to Apollo CSM attitude control system and cause of a leak in cooling system of orbital workshop. New sunshield drops workshop temperature 5 deg, to an average of about 75 deg F.

9 Skylab astronaut Dr. Owen Garriott reports that spider 'Arabella' having adjusted to weightlessness, has produced a normal web of circular pattern.

9 Soviets launch Mars 7 spacecraft by Proton rocket from Baikonur cosmodrome at 8 p.m. (Moscow time) for the exploration of Mars and surrounding space. Similar to Mars 6 with same French experiments.

10 At 2 a.m. (Moscow time) distances from Earth of four Soviet Mars probes are: Mars 4 6,432,000 km; Mars 5 5,067,000 km; Mars 6 1,535,000 km and Mars 7 102,000 km.

13 Capt. Alan Bean 'flies' 225 lb astronaut backpower manoeuvring unit (AMU) at about 2 ft/sec within Skylab workshop working 14 nitrogen gas directional thrusters with two hand controllers.

16 NASA announces 'tentative plans' to observe the comet Kohoutek during third Skylab crew mission scheduled for launch on or about 9 November. Mission is scheduled to last until 4 January 1974 with recovery in mid-Pacific 300 n. miles from Hawaii.

16 NASA selects Martin-Marietta Corporation for negotiation of a contract for the design, development, test and evaluation of the external tank for the space shuttle.

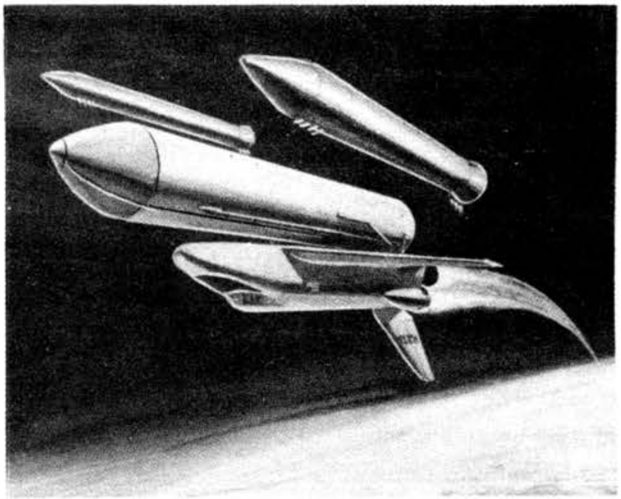
[Continued on page 417

THE SPACE SHUTTLE: SOME GROWTH POSSIBILITIES

By Robert Salkeld*

Studies by competent engineers suggest that technology soon may be equal to the task of producing one-stage-to-orbit flyback vehicles using a combination of novel vehicle designs, high-pressure engines, mixed mode propulsion and dual-fuel rocket systems. If they are correct, this could drastically improve the economics of space shuttle operation in the next decade. We invited one of the chief US exponents of 'mixed mode/dual fuel' propulsion to enlarge his ideas for possible application to the baseline shuttle and the fully-fledged single-staged orbital transport. This is his report.

Kenneth W. Gatland



The NASA Space Shuttle currently being developed has a large disposable propellent tank and twin solid-propellent boosters. The vehicle flies the first leg of its journey into space in an inverted attitude so that the aircraft-like orbiter and its flight crew are protected from high wind forces in the atmosphere by the external tank and boosters. After the solid rockets burn out and are jettisoned (as shown here) for recovery at sea the orbiter turns rightside up.

Rockwell International

Introduction

The current United States programme to develop a space shuttle is a milestone step along the road toward the practical exploration and use of space. As originally conceived when preliminary studies were begun in 1969, the shuttle programme was aimed at four primary goals: (1) reduction of space transportation costs to the vicinity of 50 to 100 dollars per pound of payload placed in low Earth orbit (it was recognised that this would be possible only if the shuttle vehicle could be made fully reusable); (2) reduction of payload costs by providing a more benign launch environment for the payload; (3) improved capability for routine manned and unmanned space operations; and (4) development of advanced rocket propulsion and aerospace vehicle technologies.

Shifting national priorities and budgetary constraints have forced NASA to replace the original two-stage fully reusable vehicle concept with the solid-boosted 2-1/2-stage current baseline configuration in which the solid rocket motors and main liquid propellent tank are jettisoned during flight [1]. As a result, the original goal of truly economical space transportation has of necessity been de-emphasized [2], and the shuttle programme is now oriented mainly toward enhancing space operational capability, reducing payload costs, and improving vehicle technologies.

That pursuit of the programme, even under these less than ideal circumstances, makes basic sense has been well expressed through historical analogy by R. F. Thompson, Manager of the Space Shuttle Programme [1]. He notes that the settlers of the New World reached the Atlantic shores using the mature sea transportation systems of their day, the sailing ships. They then faced the necessity of developing a land transportation system able to handle on a practical basis the increasing volumes of freight and passenger traffic concomitant with opening up and developing the interior of the continent. Thus began the railroads in the New World, and because at first they were not sufficiently economical to be self-supporting, their development and intial operation were subsidised with public funds.

It seems meaningful to extend this analogy in the following way. Imagine that in those early days railroad technologies were sufficiently primitive that after each round-trip between St. Louis and New York, the locomotive had to be dumped into the Mississippi River. Even under that circumstance it seems possible that we still would have proceeded to develop some kind of primitive railroad system, uneconomical though it might have been, simply because pack horses, wagons and stage coaches were physically incapable of effectively handling the necessary traffic. Perhaps such a system might actually have enabled us to commence development and use of the resources of the interior, at however a slow and difficult pace. As methods began to appear, however, whereby it would be feasible to build trains having reusable locomotives, it seems certain that we would have taken steps in that direction as soon as possible.

Such is the situation which appears to be emerging in connection with the space shuttle. Within the last two years several observers, including von Braun and Mueller, have seriously noted the reusable one-stage-to-orbit shuttle as a technical possibility [3, 4]. Others including the Boeing Company, Cleaver, Beichel, and the present author, have described in some detail how such vehicles might be made feasible [5, 6, 7]. As described in Ref. 7 projective studies of reusable single-stage shuttles date back more than a decade. Not until recently, however, have a combination of conceptual and technological advances begun to justify more immediate concern with such possibilities.

Thus, there appears sound reason to begin exploring how the current baseline programme could lead to more effective space shuttle capabilities, either through progressive improvements to the baseline vehicle itself, or through combining the technologies provided by the current programme, in a manner which would produce fully reusable one-stage-to-orbit shuttles.

The reusable single-stage concept appears particularly interesting in view of the possibility shown in Ref. 8, that such a vehicle could be converted directly to a global-orbital commercial transport essentially by exchanging its on-orbit rocket engines and propellents, for landing air-breathers. It appears that the basic vehicle and main propulsion systems

* *System Development Corporation, 2500 Colorado Avenue, Santa Monica, California 90406, U.S.A.*

would be fully applicable to both missions.

Rockets vs Air-breathers

Numerous investigations of advanced shuttle-type vehicles have been directed toward air-breathing concepts, since they would offer several advantages over rockets: (1) they would be less noisy than rockets on takeoff and thus could depart from existing airstrips; (2) they could use existing facilities with only minor modifications for maintenance and turnaround; (3) they could take off and land in the conventional horizontal attitude, which some of the rocket concepts could not; (4) their acceleration profiles would be similar to those of conventional aircraft, whereas the rockets would involve accelerations ranging from weightlessness to perhaps 3 g's; and (5) some studies have indicated that once developed, air-breathing vehicles may offer economic advantages over rockets. We have grown accustomed to air-breathers as a mode of transportation, and in some ways it may seem the most natural thing simply to continue extending familiar air-breathing technologies to cruise engines at faster speeds and higher altitudes.

On closer examination, however, it is clear that unlike past experience with aircraft development, the technologies necessary for advanced (hypersonic) air-breathers cannot spontaneously evolve as direct outgrowths of current subsonic and supersonic engineering knowhow [9]. Instead, hypersonic air-breathers for aerodynamic cruise at velocities beyond Mach 4-5 must be considered a new family of propulsion and structural technologies in themselves, requiring very large capital investments in new and specialised ground and flight test equipment. At such Mach numbers, there are complex interactions between engine and airframe design, requirements for active skin cooling, structural insulation imposed by long-duration heating, and stringent configurational constraints associated with the aerodynamics of hypersonic cruise. Thus, if the potential advantages of hypersonic air-breathers are to be realised, major technical problems must be overcome for which neither currently evolving airliner nor space shuttle developments will provide an adequate technological base.

Advanced rocket shuttles, however, could be based directly on the technologies now being developed in the space shuttle programme [10]. High-pressure rocket engines, reusable (uncooled) thermal protection systems, lightweight structures, vehicle controls and other advanced subsystems, are now being developed for shuttle operations in the late 1970's. Using this technology as a base, it seems reasonable to expect that improved, even fully reusable rocket shuttles will soon be technically feasible and could be brought to operational status by the mid-1980's. Therefore, the remainder of this article will focus on rocket concepts only.

Vehicle Concepts

Several kinds of growth steps have been studied, which could improve both the performance and economic effectiveness of the baseline shuttle hardware. Three classes of growth options are considered here: (1) replacement of the solid rocket motors with a fully reusable booster (here called 'Growth A'); (2) replacement of both the solid motors and the external tank with a fully reusable booster ('Growth B'); and (3) replacement of the entire baseline shuttle with a fully reusable single-stage vehicle ('Growth C'). Each of these growth options includes several alternative vehicle concepts including vertical and horizontal takeoff and landing, and

OPN'L. CONCEPT	PROPULSION CONCEPT / GROWTH OPTION	GROWTH A (REPLACE SRM's)	GROWTH B (REPLACE SRM's & EXTERNAL TANK)	GROWTH C (REUSABLE SINGLE-STAGE)
HTOHL (REUSABLE)	SINGLE-MODE	CONFIGURATION IMPRACTICAL	SCALING PROBLEMS (VEHICLE VERY LARGE, SENSITIVE)	REF. 6 (REQ'S. GROUND ACCELERATOR)
	MIXED-MODE		NOT YET STUDIED (PERF. & SIZE BENEFITS; HIGHER LIFTOFF SPEED)	
VTOHL (REUSABLE)	SINGLE-MODE	REF. 11	SCALING PROBLEMS (VEHICLE VERY LARGE, SENSITIVE)	NOT YET STUDIED (REQ'S. IMPROVED STRUCT. TECHN.)
	MIXED-MODE	M-M NON-OPTIMUM FOR LOW-Δv FIRST STAGES	REF. 13 (PERF. & SIZE BENEFITS)	REFS. 5, 17 (PERF. & SIZE BENEFITS)
VTOVL (REUSABLE)	SINGLE-MODE	REF. 12 "RETRO-LOB"	REF. 14	REF. 17
	MIXED-MODE	M-M NON-OPTIMUM FOR LOW-Δv FIRST STAGES	NOT YET STUDIED (PERF. & SIZE BENEFITS)	
VTO (PARTIALLY REUSABLE)	SINGLE-MODE	PRESSURE-FED BOOSTER STUDIES (ABANDONED)	NOT YET STUDIED	NOT APPLICABLE BY DEFINITION
	MIXED-MODE	M-M NON-OPTIMUM FOR LOW-Δv FIRST STAGES	REF. 15 (PERF. & SIZE BENEFITS)	

HTOHL=HORIZ. TAKEOFF - HORIZ. LDG. VTOHL=VERT. TAKEOFF - HORIZ. LDG. VTOVL=VERT. TAKEOFF - VERT. LDG. VTO=VERT. TAKEOFF (& JETTISON)

Fig. 1. Shuttle Growth Concept Matrix.

both single-mode and mixed-mode propulsion. Fig. 1 is a matrix which shows some of the vehicle classes which have been studied, [5, 5, 11-16], as well as a number which apparently have not yet received serious consideration. The Growth B options in particular must at present be considered as in a very preliminary conceptual state. This matrix is not intended to be fully comprehensive; as described later, for example, there is at least one additional family of concepts which is a distinct variant of the Growth B option.

The shuttle growth concepts from the matrix in Fig. 1 are shown comparatively in Fig. 2, in which the dashed outlines represent those which have apparently received little or no study. The configurations and weights shown for these concepts are tentative scaling estimates only.

As indicated in Fig. 1, the use of mixed-mode propulsion in boosters for Growth A concepts would yield no appreciable advantage, since mixed-mode benefits begin to appear only for relatively high Δv stages, and since by definition in the Growth A concepts the booster is required to gain only a few thousand feet per second. For growth B and C, however, which involve various forms of single-stage-to-orbit vehicles, mixed-mode propulsion promises significant benefits for all HTOHL, VTOHL, VTOVL and VTO concepts. As discussed in Refs. 5, 7 and 17, because of the relatively high overall density of the mixed-mode propellents (about 55 lb/ft^3 vs. about 22 lb/ft^3 for lox/hydrogen alone), the vehicle size is

sharply reduced. Consequently, reductions are also made possible in the vehicle manufactured hardware weight and cost, and in the amount of hydrogen required, which is the most costly of the propellents involved. The mixed-mode approach can be implemented by the use of separate engines as illustrated in Refs. 5, and 17, or dual-fuel engines as described in Ref. 7.

The following description of alternate concepts will consider in turn the HTOHL, VTOHL, VTOVL, and VTO operational modes, in terms of how they relate to the basic Growth A, B and C options.

The nominal HTOHL concept (Growth C, Ref. 6) uses four lox-hydrogen Space Shuttle Main Engines (SSME) and is designed for a maximum planform loading of about 175 lb/ft^2. This is sufficiently low to permit liftoff from its ground accelerator at a speed of 600 ft/sec. Preliminary estimates indicate that mixed-mode propulsion could be utilized in a vehicle of this type giving, for the same gross liftoff weight (GLOW), about 25% reduction in vehicle length and a payload increase of approximately 35,000 lb. Incorporating mixed-mode propulsion would increase liftoff planform loading from about 175 lb/ft^2 to about 300 lb/ft^2, requiring an increase in liftoff speed from 600 ft/sec. to 850 ft/sec. (Mach 0.75 at sea level). This would appear reasonable for the kind of ground accelerator considered in Ref. 6. Thus, the mixed-mode HTOHL appears potentially promising and might merit investigation for either Growth B or Growth C application, as indicated in Fig. 2. A mixed-mode HTOHL vehicle might utilize either: (1) high-pressure lox-cooled lox RP (or lox/RJ-5*) engines for liftoff and early ascent, and SSME's for final ascent to orbit; or (2) one less lox/RJ-5 engine with dual-fuel engines [7] in place of the SSME's. It is possible that the HTOHL requirement for a ground accelerator might be avoided by taking off empty or nearly empty using the main landing gear for takeoff roll, and then fuelling in flight. This would substitute the alternate requirement for a new heavy-lift tanker which could transfer cryogenic propellents at up to ten times or more, the rates presently attained with standard jet fuel.

The nominal VTOHL concept (Growth C, Refs. 5, 7) is a mixed-mode vehicle using 10 high-pressure lox/RJ-5 engines for liftoff and early ascent, two of which are dual-fuel engines which change to lox/hydrogen operations about 200 sec. after liftoff, for final ascent to orbit. As shown, this vehicle can be scaled up to perform the Growth B mission at a GLOW of about ten million lbs. and a vehicle length of about 230 ft., about equal to the length of a 747 airliner. Compared to the nominal mixed-mode VTOHL, a typical lox/hydrogen VTOHL vehicle designed for the same payload, as seen in Fig. 2, may be as much as eighty percent heavier in manufactured hardware weight, even assuming low dry weights possible only with advanced structural technologies of the future. In the foreseeable future, the only practical means for performing the reusable single-stage-to-orbit mission in the VTOHL mode may be through use of mixed-mode propulsion.

The nominal VTOVL concept (Growth C, Ref. 16) is a single-mode lox/hydrogen vehicle having a number of lox/hydrogen engines (which could be SSME's) arranged around a truncated plug nozzle, the nozzle being hydrogen-cooled during engine firing and also during tail-first re-entry when it serves also as the thermal shield. As discussed in Ref. 7, this class of vehicle has for the past decade been recognised as potentially feasible in the single-mode version because of its inherently low dry weight resulting from : (1) the possibility of using spherical propellent tanks; (2) avoidance of the weight penalties associated with wings; and (3) the efficiencies resulting from the multiple functions of the plug-nozzle/thermal-shield. For VTOVL also, however, as noted in Ref. 17, mixed-mode propulsion promises significant benefits: (1) over 100% improvement in payload: inert-weight ratio; (2) over 65% reduction in propellent volume for a given GLOW; and (3) over 20% in absolute inert weight for a given GLOW. An exception, as noted above, is the Growth A 'retro-lob' application. Because of the relatively low Δv required by the booster in the Growth A VTOVL application (even including the Δv necessary to reverse its in-flight direction and 'lob' itself back to the launch site), mixed-mode would not be preferred in this case and the high-density lox/RP (or RJ-5) would be preferable to lox/hydrogen (as was also found in Ref. 11 for the VTOHL Growth A case).

The nominal VTO concept (Growth B, Ref. 15) is a mixed-mode vehicle using high-pressure lox/RJ-5 engines mounted on the aft end of an external tank for liftoff and early ascent, after which lox and hydrogen are cross-fed to the orbiter and burned in the three orbiter SSME's for final ascent to orbit. The liftoff engines may then be disconnected in orbit and returned to Earth in the orbiter payload bay for reuse. The relatively high density of the mixed-mode propellents permits the external tank in this concept to be only slightly larger than the current baseline lox/hydrogen external tank. In contrast, a single-mode VTO would require a much larger tank, as shown in Fig. 2.

In the Growth B option, the three SSME's on the baseline would no longer be needed. If these engines and their associated subsystems were removed and the baseline orbiter were to be used in otherwise unmodified form, then ballast would be required to maintain the necessary vehicle balance characteristics. Alternatively, the orbiter could be extensively modified, or redesigned 'from scratch', as a pure glider. It appears likely that a redesigned orbiter-glider would be substantially lighter than the current orbiter, and if so this would consitute a major variant of Growth B, in effect a fourth option which might offer both technical and economic advantages.

What an improved space shuttle should be like, cannot be determined until detailed design, operational and economic studies and comparative analyses are accomplished. The example concepts shown in Fig. 2 were formulated by different sources at different times and presumably not under the same ground rules. Therefore, no hard comparisons can be made. However, it seems not unreasonable to attempt some qualitative observations of the type shown in Fig. 3. These observations are intended only to identify some of the main considerations which would be relevant to a comparative analysis; no attempt is made to weight the criteria or draw firm conclusions.

Yet certain indications suggest themselves at this point: (1) few would argue that to be truly economical, the growth space shuttle must be fully reusable. Therefore, the Growth A and Growth B-VTO options would not appear to be viable candidates since they are burdened by expendable hardware as well as other relative disadvantages as shown by Fig. 3; (2) few would argue that in aiming at reusable one-stage-to-

* *RJ-5 ('Shelldyne-H') is a comparatively conventional synthetic cyclic hydrocarbon having about the same specific impulse as standard JP and RP fuels, but a density about 35% higher than that of JP and RP [18].*

Fig. 2. Comparison of Shuttle Growth Concepts.

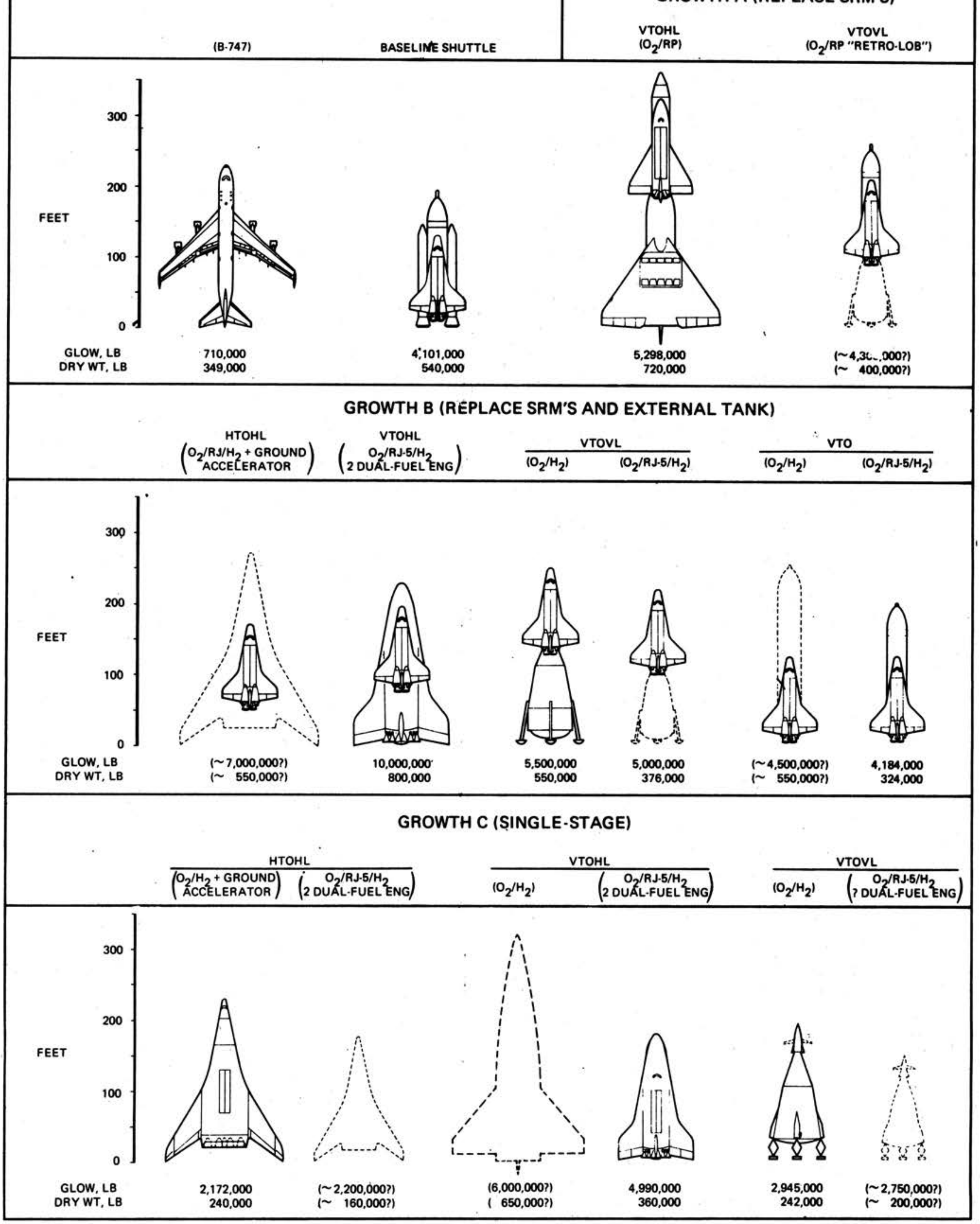


Fig. 3. General Comparative Observations for Shuttle Growth Concepts.

INDICATES RELATIVE ADVANTAGE

CHARACTERISTICS			GROWTH A		GROWTH B						GROWTH C					
			VTOHL	VTOVL	HTOHL	VTOHL	VTOVL		VTO		HTOHL		VTOHL		VTOVL	
			(O_2/RP)	(O_2/RP)	$(O_2/RJ/H_2 + ACCEL.)$	$(O_2/RJ/H_2$ 2D.F. ENG.)	(O_2/H_2)	$(O_2/RJ/H_2)$	(O_2/H_2)	$(O_2/RJ/H_2)$	$(O_2/H_2 + ACCEL.)$	$(O_2/RJ/H_2$ 1D.F. ENG.)	(O_2/H_2)	$(O_2/RJ/H_2$ 2D.F. ENG.)	(O_2/H_2)	$(O_2/RJ/H_2$?D.F. ENG.)
TECHNICAL	PERFORMANCE	PAYLOAD	COMPARABLE													
		GROWTH POTENTIAL (W/SECOND STAGE)	CONFIG. LIMITED		SIGNIFICANT						CONFIG. LIMITED		SIGNIFICANT			
	DEVELOPMENTS REQUIRED	PROPULSION	NONE	NEW PLUG	NONE	NEW DUAL-FUEL	NEW PLUG		NONE	NEW O_2/RJ	NONE	NEW DUAL-FUEL	NONE	NEW DUAL-FUEL	NEW PLUG	
		STRUCTURES	SHUTTLE/SST LEVEL	BALLISTIC	ADVANCED	SHUTTLE/SST LEVEL	BALLISTIC				ADVANCED			SHUTTLE/SST LEVEL	BALLISTIC	
		AVIONICS	ON-BOARD CHECKOUT													
	VEHICLE CHARACTERISTICS	LENGTH, FT	320	260	270	230	250	220	* 250	200	231	175	321	178	192	155
		DRY WT., LB.	720,000	~400,000?	~550,000?	800,000	~550,000	376,000?	550,000?	324,000	240,000	~180,000?	646,000?	360,000	242,000	~200,000?
OPERATIONAL	LAUNCH AZIMUTH		LIMITED BY TANK IMPACT		BOOM LIMITATION?	NO SPECIAL LIMITS					CLIMBING TURN; BOOM LIMITATION?		NO SPECIAL LIMITS			
	ABORT SAFETY	BOOSTER	REQ'S JETTISON EXTERNAL TANK		FLYAROUND OR HOVER BURNOFF HORIZONTAL OR VERTICAL LDG.				REQ'S. JETTISON BOOSTER		FLYAROUND OR HOVER BURNOFF, HORIZONTAL LDG.				HOVER BURNOFF VERTICAL LDG?	
		ORBITER	AERODYNAMIC OR PROPULSIVE GETAWAY-HORIZONTAL LDG.												PROP. GETAWAY, HORIZ. LDG.	
	RE-ENTRY HEATING	BOOSTER	"LOW" SPEED,		LOW PLANFORM LANDING	SHUTTLE LEVEL	REQ'S. ACTIVE COOLING		NOT APPL.		LOW PLANFORM LOADING		SHUTTLE-LEVEL		REQ'S. ACTIVE COOLING	
		ORBITER	BASELINE ORBITER												SHUTTLE LEVEL	
	CROSS-RANGE	BOOSTER	INHERENT	NOT NEEDED	INHERENT		REQ'S. SEP. VEHICLE OR PROPULSION		NOT APPL.		INHERENT				REQ'S. SEP. VEHICLE OR PROPULSION	
		ORBITER	INHERENT												INHERENT	
	LANDING	BOOSTER	EXISTING AIRSTRIPS	REQ'S. NEW SITES	EXISTING AIRSTRIPS		REQ'S. NEW SITES		NOT APPL.		EXISTING AIRSTRIPS				REQ'S. NEW SITES	
		ORBITER	EXISTING AIRSTRIPS												EXISTING AIRSTRIPS	
	SELF-FERRY	BOOSTER	INHERENT	REQ'S. MAIN PROPULSION	YES (AUX. AIRBREATHERS)		REQ'S. MAIN PROPULSION		NOT APPL.		YES (AUX. AIRBREATHERS)				REQ'S. MAIN PROPULSION	
		ORBITER	YES (AUXILIARY AIRBREATHERS)												YES (AUX. AIRBREATHERS)	
	FACILITIES, TURNAROUND	BOOSTER	CONVENTIONAL		REQ'S. GND. ACCEL.	CONVENTIONAL					REQ'S. GROUND ACCELERATOR		CONVENTIONAL			
		ORBITER	CONVENTIONAL													
PASSENGER CONVENIENCE (GLOBAL TRANSPORT MODE)	TIME (LAUNCH TO DESTINATION)		<2 HR												REQ'S SHUTTLE FROM LDG. SITE	
	LAUNCH ATTITUDE		VERTICAL LAUNCH LESS FAMILIAR		CONV.	VERTICAL LAUNCH LESS FAMILIAR					CONVENTIONAL		VERTICAL LAUNCH LESS FAMILIAR			
	ACCELERATION PROFILE		0 3g													
ENVIRONMENTAL	ENGINE NOISE		REQUIRES REMOTE LAUNCH													
	SONIC BOOM		BASELINE ORBITER		HEAVY GLIDER (BOOSTER)		ADVANTAGE ON RE-ENTRY		BASELINE ORBITER		CLIMBOUT BOOM?		HEAVY GLIDER		ADVANTAGE ON RE-ENTRY	
	POLLUTION		NO OXIDES OF NITROGEN; LITTLE STRATIFICATION													
ECONOMIC			EXPENDABLE HARDWARE		(UNMANNED BOOSTER?)		POTENTIALLY FAVORABLE		EXPENDABLE HARDWARE		POTENTIALLY FAVORABLE		VERY LARGE VEHICLE	POTENTIALLY FAVORABLE		

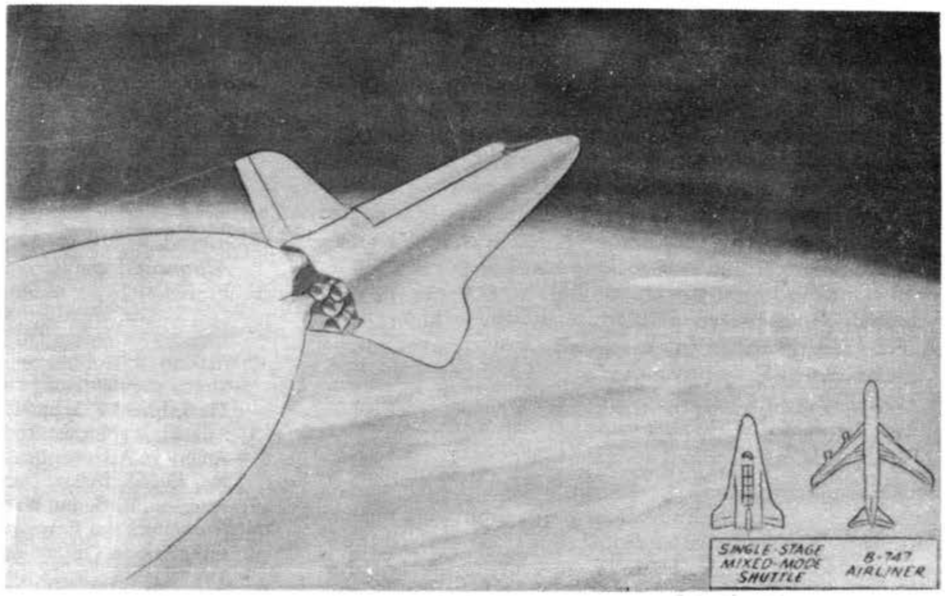


Fig. 4. Reusable One-Stage-to-Orbit Shuttle (Application of Mixed-Mode Propulsion to Vertical-Takeoff-Horizontal Landing Vehicle).

All illustrations: System Development Corporation.

orbit capability, it is mandatory to strive for all the performance gains which are reasonably attainable (without, of course, unduly compromising the economic or operational viability of the vehicle). Therefore, in view of its promise of performance benefits (as well as size and potential cost advantages) for each of the remaining Growth B and C options, mixed-mode propulsion would appear to be a key element for shuttle growth. This approach would call for developing a new high-pressure lox-cooled lox/hydrocarbon engine, perhaps with dual-fuel adaptability, but as shown in Ref. 7 this requires no basic engine technologies beyond those already being provided by the SSME development programme; (3) the Growth C option appears to offer a number of advantages over Growth B (and its variant mentioned above); however, Growth B provides the inherent bonus of a heavy launch capability, and if mission requirements should develop for such capability, then Growth B might be preferable. A significant economic consideration for Growth B is that the one-stage-to-orbit boost vehicle could be developed and operated as an unmanned device, possibly at lower development and operational costs than if it were manned; (4) although it appears that there may be a net advantage of the VTOHL over the other modes, any conclusion in this regard would at this point be premature. Perhaps a relevant observation here would be that, with respect to technological and design approach, HTOHL vehicles may be more related to aircraft know-how, VTOVL to ballistic missile experience, and VTOHL to some combination of the two, such as may be emerging in the current shuttle programme. Thus, eventual selection from among the three might depend on organisational and policy factors as well as technical considerations.

In the light of the above considerations, it would appear that at least four growth shuttle concepts can be identified as potentially promising possibilities, all being reusable one-stage-to-orbit devices; (1) a VTOHL mixed-mode shuttle (possibly unmanned) capable of placing the baseline orbiter (or a lighter pure glider) in low polar orbit; (2) a VTOVL mixed-mode shuttle (possibly unmanned) capable of placing the baseline orbiter (or a lighter pure glider) in low polar orbit; (3) an integral HTOHL mixed-mode (manned) shuttle having its own payload bay and capable of placing the mission payload in low polar orbit; and (4) an integral VTOHL mixed-mode (manned) shuttle having the same capability. Such a vehicle is illustrated in Fig. 4.

Environmental Considerations

Primary environmental considerations with regard to space shuttles are atmospheric pollution, sonic booms and engine noise.

Any rocket vehicle such as these considered here, which burns pure oxygen with fuels containing no nitrogen, offers distinct advantages with respect to atmospheric pollution, since the rockets therefore produce no oxides of nitrogen. It has been suggested that the nitrogen oxides from aircraft exhaust could stratify in the upper atmosphere, reduce ozone concentrations below their natural levels and thus result in increased exposure of people on the ground to ultraviolet solar radiation and resultant medical side-effects. It is uncertain whether this suggested problem has any sound basis in fact, and the question is still under debate within the technical community [19]. However, such a possibility does not exist with any of the vehicles in Fig. 2, which use only oxygen, hydrogen and hydrocarbons. The major exhaust products would be water vapour and carbon dioxide, neither of which is now considered to pose significant pollution problems [19]. Some unburned hydrocarbons would also be present, but within acceptable limits.

An inherent advantage of these growth shuttle concepts as compared with the current baseline shuttle, is that they eliminate the problem of the exhaust from the solid rocket motors, over 20% of which (by weight) is hydrochloric acid.

An inherent advantage of rockets over air-breathers is that rockets climb much more steeply through the atmosphere and therefore create less possibility for stratification of ex-

haust products.

With respect to sonic booms, the steep ascent of the rocket appears to remove most if not all of the problem of sonic boom during climb and acceleration, although some boom control may be necessary near the end of glide [10].

Noise levels of the rocket engines at takeoff are such that they probably will require remote launch facilities. The degree to which noise limits for turbine-powered aircraft operations can be extrapolated to include rockets is at this point quite uncertain – for example, the shorter duration of rocket airport noise due to the steep climbout might render higher noise levels acceptable. In any case, unless quiet rocket engines are developed (and prospects for this do not seem promising), it appears clear that takeoff noise restriction must be a key factor in shaping rocket transport operations.

Observations

1. There are several growth possibilities for improving the performance, economics, and operational viability of the current baseline shuttle. These improvements could evolve as direct outgrowths of the propulsion, materials, and aerodynamic technologies being developed in the current shuttle programme. (It appears most realistic to consider such growth in terms of pure rocket propulsion only, since high-Mach-number airbreathing engines will probably not be operationally practical until relatively far in the future).

2. For almost all growth concepts irrespective of vehicle configuration, mixed-mode propulsion promises significant advantages in the form of improved performance, reduced vehicle size and manufactured hardware weight, and reduced propellent costs.

3. The only growth concepts which would make basic sense, in terms of economic effectiveness and operational viability, are those in which the vehicle hardware would be fully reusable.

4. There appear to be at least four growth options sufficiently attractive to merit investigation: 1) a VTOHL mixed-mode shuttle (possibly manned); 2) a VTOVL mixed-mode shuttle (possibly manned); 3) an integral HTOHL mixed-mode (manned) shuttle; and 4) an integral VTOHL mixed-mode (manned) shuttle.

5. Rockets burning liquid oxygen with hydrocarbon and hydrogen fuels containing no nitrogen, appear favourable with respect to atmospheric pollution, since the rockets produce no oxides of nitrogen. Further, the steep ascent of the rockets results not only in little exhaust stratification, but also sharply reduces or eliminates sonic boom during climbout and acceleration.

6. The reusable single-stage concept appears particularly promising since such a vehicle might also serve with straightforward modification as a global commercial transport, promising dramatic advances in international commerce and cooperation.

REFERENCES

1. Thompson, Robert, F., 'The Space Shuttle Programme and its Technology', American Astronautical Society 19th Annual Meeting, Dallas, Texas, 19-21 June 1973.
2. 'Analysis of Cost Estimates for the Space Shuttle and Two Alternate Programmes', Report of the Congress by the Controller General of the United States, B-17367, U.S. General Accounting Office, Washington, D.C., June 1973, pp. 11-12.
3. von Braun, W., 'Prospective Space Developments', *Astronautics and Aeronautics,* 10, 4, April 1972. p. 30.
4. Mueller, G. E., 'Space Shuttle: Beginning a New Era in Space Cooperation', *Astronautics and Aeronautics,* **10**, 9, September 1972, p. 21.
5. Salkeld, R. 'Mixed-mode Propulsion for the Space Shuttle', *Astronautics and Aeronautics,* 9, 8, August 1971, pp. 52-58.
6. Feasibility Study of Single-Stage-to-Orbit Vehicle', The Boeing Co., Seattle, Washington, Air Force Contract F04701-72-C-0418, SAMSO Reference TR-72-321 (Unclassified), January 1973.
7. Salkeld, R. and Beichel, R., 'Reusable One-Stage-to-Orbit Shuttles: Brightening Prospects', *Astronautics and Aeronautics,* **11**, 6, June 1973, pp. 48-58.
8. Salkeld, R., 'Global Rocket Transports: Changing Perspectives', American Astronautical Society 19th Annual Meeting, Paper No. 73-163, Dallas, Texas, 19-21 June 1973.
9. Peterson, R. H. and Waters, M. H., 'Hypersonic Transports – Economics and Environmental Effects', Eighth Congress of the International Council of the Aeronautical Sciences, Amsterdam, The Netherlands, 28 August –2 September 1972.
10. Love, E. S., 'Advanced Technology and the Space Shuttle', *Astronautics and Aeronautics,* **11**, 2, February 1973, pp. 30-66.
11. 'Shuttle Systems Evaluation and Selection: Volume IV, Booster Data', NASA Contract No. NAS9-11160, Mod. No. 105, B35-43-RP-30, The Boeing Company, Seattle, Washington, and Grumman Aerospace Corp., Bethpage, New York, 15 December 1971.
12. Marion, E., unpublished study, Bellcom, Inc., Washington, D.C., 1969.
13. Unpublished study, System Development Corporation, Santa Monica, Calif., June 1973.
14. Bono. P., private communication, December 1971.
15. Unpublished study, System Development Corporation, Santa Monica, Calif., March 1972.
16. Gomersall, E. W. and Hornby, H., 'A Single-Stage-to-Orbit Shuttle Concept', NASA-OART Mission Analysis Division Working Paper MA-70-2, 20 July 1970.
17. Salkeld, R., 'Contribution to the Discussion of Mixed-mode Propulsion and Reusable One-Stage-to-Orbit Vehicles', System Development Corporation, Santa Monica, Calif., Report SP-3677, presented at the 23rd International Aeronautical Congress, Vienna, Austria, 8-15 October 1972.
18. 'Hydrocarbon Fuels for Advanced Engines', Shell Development Co., Report AFAPL-TR-70-71, Part II, September 1971.
19. Johnson, F. S., 'SSTS, Ozone and Skin Cancer', *Astronautics and Aeronautics,* **11**, 7, July 1973.

SKYLAB – THE DIARY OF A RESCUE MISSION

By David Baker

Continued from October issue, page 383]

Mission Day 26 (Continued)

Due to the extra time allowed following the early and short extra-vehicular activity (EVA) the French ultraviolet panorama experiment was performed again, in addition to other minor corollary tasks. The only major anomaly concerned the secondary coolant loop in the CSM. A temperature transducer remained in the 'on' position despite power offload from that circuit, indicating that if the temperature cooled on the exterior the heaters would activate and warm the static coolanol, heating the pipe and rupturing the plumbing. A work-around was being developed for entry day. The beta angle now showed 63° and this provided some 8000 watts of available electrical power. In addition, 17 of the 18 CBRM units fed from the ATM arrays were functioning as planned, due to the efforts of Conrad in tapping free the stuck relay on CBRM-15 providing remaining Skylab missions with adequate power for a full programme.

Mission Day 27:

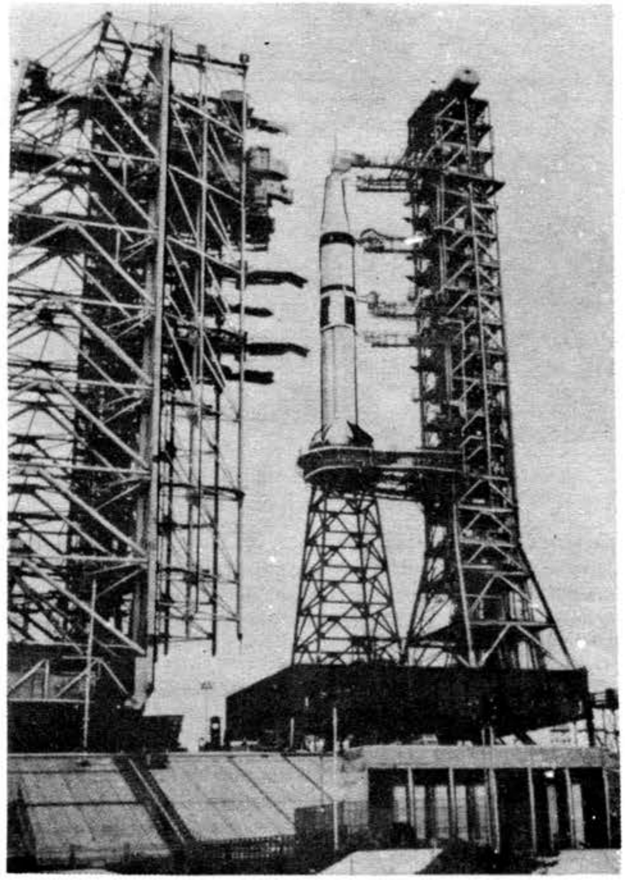
The crew, after being allowed to sleep on for a extra few minutes,were woken at 2:18 a.m. The entire day was spent in deactivation and equipment transfer. A press conference was held with the ground shortly after 5:00 a.m. During the day Weitz was test subject on the LBNP and the ergometer, monitored by Kerwin who later deactivated these and the other medical experiments. Considerable time was spent in stowing the equipment and collecting a long list of transferable items. The crew requested that they go to bed 1 hour early, at 5:00 p.m. for 8 hours, to prepare themselves for the even earlier sleep start on the final night. Houston concurred and the last communication was completed at 4:35 p.m. By now the cluster was in complete daylight for the entire orbit and the electrical availability had risen to the maximum of 9200 watts. The internal OWS temperature had risen slightly to level at 26.5°C.

Mission Day 28:

Deactivation day saw the crew woken at 1:09 a.m. During this shortened, 13½ hour day the entire cluster was configured to lie quiescent for some 36½ days until the second mission crew would arrive to double the accomplishments of the first. Several times the crew were hours ahead of the check lists and were it not for a problematical urine separater not fitting the waste lock the sleep period scheduled to begin at 2:30 p.m., may have begun earlier. Among other less prominent duties the crew placed the particle collection experiment in the anti-solar airlock to be retrieved by SL-111. By 2:13 p.m. the last call had gone out to the crew and they settled down for their last, abbreviated sleep period aboard Skylab.

Mission Day 29:

Although the astronauts were scheduled to end their rest period at 7:30 p.m. it was 7:47 before the first communication was held with Mission Control. Within an hour they were activating the command/service module, an operation that was scheduled to take nearly 3 hours. Conrad was in the command module during this time while Kerwin configured the ATM control and display console for its unmanned role and Weitz was busy assisting both astronauts. By 9:15 p.m. Conrad was powering up the service propulsion system that would twice be called upon to de-orbit the spacecraft. At 11:10 p.m. Mission Control led troubleshooting activities on the primary refrigeration loop responsible for serving the food freezers, wardroom freezers, urine freezers, urine chillers and the water chiller in the OWS. This loop is not to be confused with the primary and secondary airlock module coolant loops that had caused trouble throughout the mission. The primary refrigeration loop was normally holding the freezers at 1-2° below zero C but indications were that it had risen to 1.5°C and at 2°C the secondary loop would cut in automatically. At acquisition of signal through the Honeysuckle station, at 12:04 a.m., it did just that. Twenty minutes later a plan was proposed to pitch the cluster 45° for ½ to 1 orbit thereby warming the radiator which was apparently frozen. The high beta angles may have altered the albedo reflection from the Earth and cooled it below the threshold. By 12:45 a.m. all three crewmen were in the command module preparing for closeout. At 1:06 a.m. the station in space lost contact through the Canary Island tracker with an advisory that the CSM may be used to do the pitch manoeuvre, conserving TACS propellent. At the beginning of manned operations some 44.4% propellent remained and only 1.1% had been used thus far. At precisely 1:43:20 a.m. the ground commanded Skylab to pitch 45°. The hatch had been installed in the command

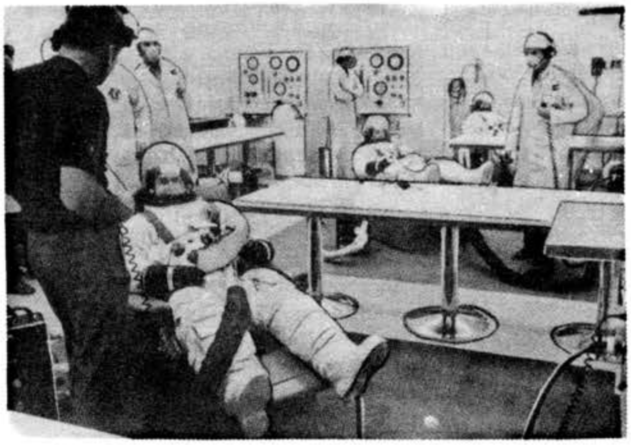


Two-stage Saturn IB rocket stands poised to launch the second Skylab team of astronauts, Alan L. Bean, Dr. Owen K. Garriott and Jack R. Lousma, to the orbiting space station following the triumphant repair carried out by Charles Conrad, Joseph Kerwin and Paul Weitz.

National Aeronautics and Space Administration

Crewmen prepare for the next round. Reviewing flight plans in their quarters are the second Skylab team, *left to right,* Dr. Owen K. Garriott, Science Pilot; Jack R. Lousma, Pilot; and Alan L. Bean, Commander. Assisting are flight crew support personnel Ray Dell'Osso (standing) and Elmer Taylor (seated in foreground).

National Aeronautics and Space Administration



Donald K. Slayton, Chief of Flight Crew Operations at the Johnson Space Center, reviews flight plan with Skylab Commander Alan Bean during pre-launch suiting activities. Bean, with Dr. Owen Garriott in centre couch and Jack Lousma, in rear, were launched aboard the Saturn IB rocket from Complex 39B at 7:11 EDT on 28 July 1973.

National Aeronautics and Space Administration

module and tunnel venting begun some 7 minutes earlier and by 2:24 a.m. the pressure reading was zero. Ten minutes later the Canary tracking station started the cluster back in to solar inertial attitude. Due to settling perturbations in the stabilisation gyros the crew were given a no-go for undocking at 3:34 a.m. over the Guam tracking station. Twenty-two minutes later the Goldstone station rescinded this command and at 3:58 a.m. the CSM slipped its shackles and drifted away from Skylab. At precisely 4:40 a.m. after the CSM had flown around the workshop on an inspection and picture-taking exercise the RCS engines burned a 5 ft/sec. separation manoeuvre with the spacecraft 2,000 nm south of Madagascar. The SPS-1 shaping burn, a 10 second burn removing 264 ft/sec. from the forward velocity, came at 5:05:30 a.m. as the CSM passed over the Phillippine Sea, starting it toward a perigee of 90 nm. Just before the spacecraft lost contact with the Carnarvon station the crew were advised that their burn had been so perfect that no updates were necessary for all the following operations. This information was passed up at 6:28 a.m. On the spacecraft swept, through the Goldstone tracking station and on to Vanguard. Contact was lost with Vanguard at 7:33 a.m. and no more communications would be held, or contact established, until the spacecraft was in the atmosphere on its way to a Pacific Ocean splashdown. At 8:10:43.8 a.m. the SPS engine burned for 7 seconds in a 190 ft/sec. manoeuvre that would de-orbit the command and service modules. Separation of the two components came at 8:15:50 and at 8:33:47 a.m. the command module hit the upper layers of the atmosphere. On through blackout the crew were finally able to talk to the ground through an IRIA aircraft at 8:43 a.m., 40,000 ft. above the quiet waters of the Pacific. Splashdown came at exactly 8:49:48 a.m. after a flight lasting 28 days 49 minutes 48 seconds. It was reported that the command module was 6½ nm from the recovery ship *USS Ticonderoga*, and that the *Ticonderoga* was 6½ miles from the splashdown co-ordinates! By 9:28 a.m. the 912 ft. long carrier had manoeuvred alongside, winched up the spacecraft and set it down on its support dolly.

The condition of the crew was a remarkable vindication of the learning that had been brought to bear on the problem of long duration space flight through the Gemini and Apollo Programmes. Conrad seemed to have adapted with less recovery symptoms than Weitz, and Kerwin was markedly affected by the return to 1g and his vestibular disorientation was noticably more severe than that suffered by his colleagues. Pre-flight crew weight for Conrad, Kerwin and Weitz were 9 st. 10.75 lb. 12 st. 3.25 lb. and 12 st. 7.25 lb. The first post-flight weights tests showed these weights to have dropped by 4.05 lb. 7.50 lb. and 7.50 lb. respectively. Within 4 to 5 days even Kerwin was well on his way back to the pre-flight baseline on the LBNP, ergometer, and other calibrated tests. This must surely be seen as evidence that Man was not made for Earth alone and that even the 56 day stay of the second and third crewmen are but precursors of much longer excursions beyond the environs of Earth.

Acknowledgement

In the preparation of this Skylab Diary the author has used original tapes, transcripts and data files to compile a chronology of a few of the many significant events associated with the activities of Skylab Mission 1. Several points in the Diary diverge from the published information and are at variance with statements and records issued in-flight by the Public Affairs Officers at the Johnson Space Center. Initial reports are always subject to erroneous details and in recognition of the outstanding performance of the NASA Public Affairs staff this Diary is dedicated to their efforts. It should not be felt that presentation of 'corrected' information reflects in any way on the magnificent job undertaken for 43 days of hectic and eventful activity by the Public Affairs staff; rather it should stand to indicate the very few errors collated and published for general distribution.

SPACE AND THE HISTORIAN*

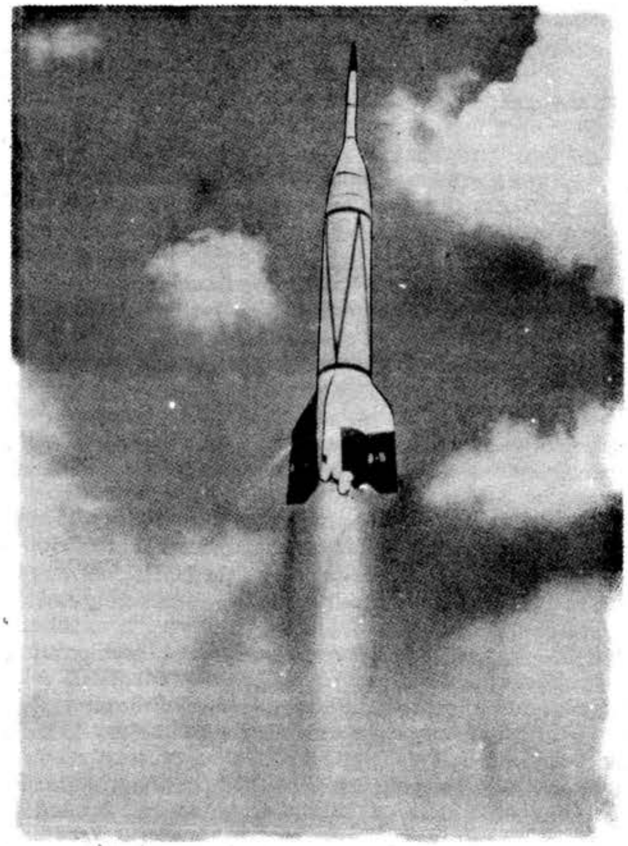
By Dr. Eugene M. Emme**

Introduction

The craft of the historian is to attempt to recreate the past meaningfully as it really was, in a literary form digestible by any intelligent layman, nourished by the best possible evidence. For historians of science and technology today a classic thesis of renewed intellectual interest is that of the late William Fielding Ogburn on the 'cultural lag' in human affairs [1]. Traditionally, mankind as a whole has reluctantly understood dynamic changes in scientific knowledge about nature as well as the full import of technological means available to exploit it. This 'cultural lag' has been rather well documented for the sailing vessel, the telescope, and the steam engine and, to a lesser extent, for the aeroplane and nuclear fission.

Ogburn's thesis might well be revisited in the latter decades of the 20th century. The pace and the breadth of science advances and technological innovations have presented wholesale blessings as well as challenges to the ways of earthbound society on a small planet in a small Solar System in an obscure corner of the Universe.

Until the appearance of the balloon by the 19th century and the aeroplane in the early 20th century, which opened up the air-space medium, as well as the true submarine with nuclear power, man's physical mobility was only two dimensional on the surface of the Earth. Techniques of war and peace as well as scientific inquiry and intellectual perspectives were, to differing degrees, constrained to the surface of the Earth (though speeded by the steam and petrol engines) as they had been throughout the ages. Technologically improved aviation was increasingly to exercise a 3-dimensional influence upon the pursuits of earthbound mankind, first in warfare in 1914-18 and then via air transportation which became truly economic and worldwide with the large jet transport in the late 1950's. Intercontinental military air power as well as global-legged statesmen, businessmen, politicians, artists, scholars, and tourists quickly made the consequences of their mobility felt in human affairs. Man grappled with a shrunken and bipolarized air-age world with an aeronautical technology that exploited a usable atmospheric medium only twice the height of his tallest mountains. In the mid-twentieth century, unprecedented innovations were to be brought most sharply into human comprehension and utility, beyond antibiotics and 'the pill', by the release of nuclear energy and the advent of astronautics.



In 1949 – at White Sands, New Mexico – European and United States' technology combined to launch an American WAC Corporal rocket from the nose of a German V-2. The small rocket reached a record height of 242 miles. It was the prelude to the first artificial satellites.

From 'Development of the Guided Missile' by K. W. Gatland, Illife Books Limited, London.

Increased Velocity and Breadth of Change

Space exploration was considered an unacceptable field of intellectual inquiry at the end of World War II except by a handful of physicists interested in the ionosphere, by a few missilemen and their engineering compatriots, by aeromedical men projecting the human pilot to supersonic and high-altitude flight, and, of course, by the cosmologists, small bands of rocket societies, and a few publicists [2]. The appearance of practical liquid chemical fuel rocketry with the German V-2 in the Second World War led directly to the development programmes in the United States and the Soviet Union of nuclear-tipped missiles and spacecraft possibilities. Within a decade, rocket technology had exerted a revolutionary impact upon scientific potential and technological competence. At the same moment when the modern rocket wedded to thermonuclear technology first appeared feasible, there was little comprehension of the full potential of rocketry for non-military use. The significance of the application of rocket technology to space flight

* *This paper is based on a series of lectures to historical and engineering groups over the past several years, including 'The Historiography of Rocket Technology and Space Exploration' at the 13th International Congress on the History of Science, Moscow, 19 August 1971, and the author's introduction to* 'The History of Rocket Technology: Essays on Research, Development and Utility *(Detroit, Michigan: 1964), pp. 4-10.*

** *Dr. Emme is a Fellow of the BIS, corresponding member of the International Academy of Astronautics and member of its History Committee, and the director of the Agency-wide historical programme of the National Aeronautics and Space Administration (Washington, D.C.). He is Editor of* Impact of Air Power: National Security and World Politics *(Princeton, New Jersey: 1959), author of* Aeronautics and Astronautics: An American Chronology of Science and Technology in the Exploration of Space, 1915-1960 *(Washington, D.C.: 1961) and* A History of Space Flight *(New York, N.Y.: 1965).*

– the first breaching of the last barrier to man's mobility in the Universe itself – was less well understood in the Sputnik birth of the so-called 'space age' in 1957 than was highest policy concerns of a 'missile gap' and a 'space race'. Then came NASA and, after the missions of the three *Lunar* spacecraft and *Vostok 1*, Apollo.

Twelve years after Sputnik and 8 years after Yuri Gagarin first circled the Earth in space, Neil A. Armstrong first stepped upon the surface of the Moon on 20 July 1969. Within the 16 years from Sputnik 1, there have been 47 separate manned missions: 63 men have flown in space, 12 have already walked on the surface of the Moon, 24 men have flown around the Moon and 2 men (Lovell and Young) have made 2 Apollo voyages as well as 2 Gemini Earth-orbital flights. Hundreds of scientific and applications satellites and numerous interplanetary probes have served to piece together part of the cosmic jig-saw puzzle involving the space environment of the Earth. New answers based on newly acquired space data erect new scientific questions. The swift pace and complexities characterising rocket technology and its application to space exploration and exploitation has created most important tasks for present-day and future historians. Whether the technological apex or just a beginning of the Universal era of humankind on Earth, posterity deserves a full account of how it came to pass.

Despite an existing technology in the ancient black powder fireworks of Asia and Europe and the gunpowder rockets popularized by early rocket enthusiasts, modern rocketry emerged virtually new-born as a major new technology [3]. Space exploration was made possible by liquid-fueled chemical rocketry, an evolution from the first demonstration by the American, R. H. Goddard, in 1926, and first developed to operational status in the German V-2 in World War II. The large liquid-fueled rocket as a technological innovation of war was only temporarily overshadowed by the initial impact of nuclear fission in 1945. Advanced rocketry was harnessed to thermonuclear firepower for the development of intercontinental military systems a decade later. Confusing to many laymen and historians alike is the central fact that the global-legged 'missile age' and the so-called 'space age' began at about the same historical moment, although their subsequent history has so far taken divergent paths.

The history of modern rocketry thus cannot be considered merely with the evolution of military missile systems in the late 1940's and 1950's. Launching of rockets for vertical soundings of the upper atmosphere, including some of the V-2, gave direct impetus after 1945 to the creation of the International Geophysical Year by 1954 [4]. It was also no historical accident that the first Earth satellites launched by the USSR and the United States in 1957 and 1958 – Sputnik was launched by a military missile – were launched in the name of international science for the IGY, which was to establish space science traditions carried on thereafter by all participating nations [5]. This dramatic innovation in mankind's capability, in turn, sparked space endeavours including manned flight accomplishments largely unforeseen as to the scope and the rapidity of their happening. Attempting to explain 'why' and 'how' this transpired also dictates central concerns for the professional historian trying to determine 'what' and 'who' were most centrally involved in the history of space affairs. The scope of historical inquiry should include the entire historical spectrum involving space science and technology – political, economic, and social aspects – and the international environment. This concurrently involves elements of competition as well as co-operative efforts to maintain a peaceful space environment dedicated to the pursuit of benefits for all of mankind on Earth during the exploration of the Universe [6].

With regard to rocket technology itself, the primitive scientific experiments flown on missiles evolved swiftly into new and complicated test and operational space systems. Engines, pumps, turbines, valves, tubing, tanks, gyroscopes, accelerometers, guidance and control devices, and computers adapted to space needs were improved and manufactured in large quantity. An urgent need also developed for mechanical and electronic instruments, pressure and strain guages, transducers, beacons, and recorders. New material processes and tools were modified or created – explosive forming, chemical milling, electron-beam welding, and so forth. New combinations of mechanical stress, thermal and vacuum extremes, and vibration harmonics demanded new alloys and new structures of steel and aluminium as well as greater use of other metals – tungsten, molybdenum, beryllium, titanium – better insulators of resins, glass, graphite, and rubber. Specialized ground servicing and launch-associated equipment were designed and produced, often with unique mobility and dimensions. Rocket propulsion fuels, solid and liquid, have been produced and employed in great tonnages: composite double-base solid fuels; liquid oxygen, kerosene, nitric acid, hydrazine, fluorine, and, most recently successful in Centaur and Apollo-Saturn, liquid hydrogen. Also nuclear and electric propulsion were developed and now offer promising potentials for future space applications. The technology of computers and communication had to be adapted and arranged in vast networks to serve diverse and critical needs of navigation, systems operations and control, and data telemetry [7].

Virtually a new industry – indeed, many new industries – coalesced rapidly. Technical personnel in missile and space programmes expanded from a few hundred persons in the late 1930's to hundreds of thousands in the late 1960's. The art of managing large organisations as well as the stimulus to the life sciences for manned operations proved novel challenges involving unique space-related problems [8]. The broad front of advances in space technology was based upon constant refinements of manifold systems and subsystems, including innumerable tests and repeated modifications, all aimed at the improvement of performance and reliability of operations. Advances often led to new techniques of application to earthbound uses, including new tools for science. And intrinsic to the complete history of space machines, techniques, and supporting equipments, was the role of individual men and organisations of men of various talents who helped to make it all possible when governmental and public support was achieved and maintained in several of the leading nations.

By definition, historians must always come after the event. Historians of science and technology should not miss the central theme submitted here: the vast host of important and new historical problems awaiting detailed research and sound scholarship, perhaps new techniques for valid documentation and reliable analysis, not to ignore the less laggard initiative to capture the detail and spirit from the participants in this great story in the history of mankind. Clearly, the history of rocket technology and space exploration performance must pass into the domain of dispassionate and non-participant historians. Those who helped to make history, albeit intimate to many happenings,

will consistently possess a perspective dominated by their own experiences. Only with detachment can the totality of history emerge as a coherent body of knowledge.

Thoughts on Methodology of Contemporary History

The swift arrival of practical space technology during the past two decades intimately involves the art and science of contemporary history with all of its hazards and benefits. Aerospace historians are placed into a close relationship with the yet-living history-makers themselves. As a group, major participants appear to have been much too busy to have yet had time and occasion to write their memoirs and a precious few have already passed away. Participants in this great space story seem generally concerned about their experience as it may relate to history. Their high interest and help provides added impetus for the fullest treatment of events possible by historians. A most useful exercise for perspective has been the giving of memoir papers at historical and professional conferences by history-makers [9]. On the whole, most participants seem generally willing, as their schedules do permit, to be interviewed in depth by serious minded historians. A few who have written may claim that their memoirs are histories and some participants may have been over enthusiastic about stating the historical significance of their own work and perhaps helped provoke Lewis Mumford to state: "Contemporary 'space age' prophets, who proclaim space exploration as the endless frontier and astronauts as the coming pioneers, throw a unrealistic glamour over the past, and even more, the future of such efforts". To be sure, the massive news media coverage during the exciting Apollo launchings publicized well the enthusiastic statements of many watching the product of years of their own labour [10]. It is the historian who must put events into their historical context.

Experience in contemporary historiography indicates that inviting comments of participants on draft histories serves particularly well as a part of the continuing in-depth research process. Ultimate discretion of accuracy still should reside with the individual historian, provided his documentation is impeccable and his analytical assumptions also are clearly discernible. The process of oral history interviews and comments from participants is not without hazard; a historian should become well informed about his subject so that inaccurate memories or singular viewpoints do not warp his research [11]. Oral history requires much more knowledge and skill than the operation of a tape recorder. Having one's scholarship reviewed by living participants clearly sets contemporary historians apart from their more traditional colleagues attempting to recreate a time and circumstance involving people long dead and buried. This author submits that the advantages of contemporary history far outweigh its hazards for bias and short perspectives if scholarly purposes of accurately recreating the past, however recent, are maintained uppermost. While in-depth research and subsequent analysis may be initiated with the basic documentation in hand, publication of full histories involves the inevitable controversies and problems of all human institutions. Such seem to recommend a reasonable perspective of 10 years before some sensitivities concerning people yet active can be placed in print. The History Symposia of the International Academy of Astronautics invites memoir papers as well as historical monographs covering subjects beginning more than 20 years ago from prominent historians and history-makers [12]. Contemporary history by definition cannot be successful without the assistance of or judgment by participants which becomes part of the historical documentation passed on to posterity. It remains of utmost importance that the histories be undertaken on all major phenomena.

A second characteristic of contemporary historiography is that the bulk of relevant primary documents is likely to be extant, and further, often proliferated by manifold reproductive systems from carbon paper and film to xerox and microfiche. Problems of selection and value are erected by the sheer mountains of available documentation. Historians have a particularly timely role in helping ascertain what key papers and files, data banks, film depositories, and the like should be retained and preserved for the future. Additionally, the massive bulk of current publications – official, technical, professional papers, journals, and the news media – are also readily available to the contemporary historian. The key artifacts and hardware must get in the inventories of the great museums to illustrate the physical history of space machines. Rare is the important recent event that is not well documented also by technical and commercial motion pictures and TV tapes. The live transmissions of Apollo TV cameras from the surface of the Moon to hundreds of millions of persons on Earth prompted one spokesman for journalism to challenge historians by saying: 'Once again [in 1970] the Apollo flights demonstrated that TV is the foremost chronicler of the rituals and actions of our time. No future historian is likely to improve upon those images which, on certain great occasions, it brings into the world's living rooms' [13]. What historians would maintain, of course, is that more than 'certain great occasions' in the course of history must be told and documented. Less well-known occasions, ideas, and persons take on greater significance as the full meaningful history becomes better known; the contemporary historian also ensures that future historians will not be dependent upon the random surviving documentation.

Various historical works help systematize and make more comprehensive the labours of contemporary historians of rocket technology and space exploration. The following types of studies seem basic and are offered to stimulate discussion and comment:

Bibliographies: Massive computer-geared technical bibliographies arranged by crude technical classification are helpful but generally encompass coarsely only a fraction of any subject to be covered by the contemporary historian. Rarely are motion picture and TV interviews catalogued in archives. Politicians and budget-makers are also a part of the history of science and technology. Only a few helpful critical bibliographies exist for the published literature on aerospace history [14]. It is the selective documentation of a full history which provides helpful trail-blazing qualitative bibliography. No history is complete without its own bibliography and index, which are criteria marking the work of a scholar.

Chronologies: To organize known data arbitrarily according to time, if documented, is a necessary first step toward a history. Chronologies provide a useful beginning for serious historical scholarship and seem well received the earlier they are attempted. Chronologies are not histories and are only as useful as their completeness and the quality of their sources. They have the virtue of ordering data of broad scope into a time frame and, when well documented and indexed, they

aid data retrieval. Compared to early narratives which organize data in accordance with a predetermined conceptual model, chronologies better serve all possible specialized scholars [15].

Memoirs: Key participants in recent history rarely wax autobiographical without encouragement. Some reflective speeches as well as invited papers at historical and engineering conferences provide historical nuggets worth mining. The lack of memoirs for more recent events must be overcome by recorded oral history interviews, in-depth research, and by devices to encourage history-makers to reflect upon their work before their memories fade and their files evaporate. It has proven useful to invite key participants to speak at the transfer of artifacts to aerospace museums to explain the historical meaning of the physical history. Most historians are aware that memoirs written after the passage of time often are distorted by intervening experience and some self-justification. Contemporary historians working closer to the actual events can often be of invaluable assistance to those writing memoirs [16].

Biographies and Collected Papers: Despite the proliferation of papers in the rise of 'big technology' in the 20th century, the 19th century practice of memorializing great men ought not to be allowed to atrophy or die. Publication of the papers of K. E. Tsiolkovskiy and, more recently, of R. H. Goddard, for example, ensure that primary sources not just biographies are more widely available. While the collected papers of institutions and leading individuals are rarely published because of their sheer mass, effective archival activity is indispensable to the work of future historians. Without retention and preservation of the papers of leading participants in the history of rocketry and astronautics, there can be no retrieval for their use by historians [17].

History of leading institutions: Narrative histories of professional societies, academies, institutes, governmental agencies, laboratories and industries are difficult indeed but indispensable for documenting the evolution of space activities from individuals in small groups to large programmes. Anniversaries are often helpful in getting such histories initiated, but most helpful are those professional, national, and international institutions which support a professional historical activity [18].

Histories of programmes: Specific rocket and space programmes have the advantage of having a beginning and an end, an integrated organization directed toward a clearcut objective. These histories can often be initiated effectively as soon as a programme ends. A history of Project Mercury, for example, appeared in 1966 and a history of Project Gemini is nearing completion. The history of the U.S. Apollo programme has already been initiated, although it will be some years before its volumes appear [19].

Histories of disciplines and subdisciplines of science, engineering, and management: These cannot be neglected. Perforce, a scientific discipline generally has a long evolutionary development, one compounded from conception to experimentation. Novel and massive data require time for analysis. It is difficult to treat space sciences without long perspectives until scientists agree on the meaning of new space data or on a helpful integrative theory. The significance of

Astronaut John H. Glenn, Jr., first American to orbit the Earth on 20 February 1962, returns to Cape Kennedy to report his experiences. With him are fellow astronauts Donald K. Slayton and M. Scott Carpenter. *NASA*

the discovery of lunar-like surface formation on the surface of Mars by Mariner 4 in 1965, and recently Earth-like surface features by Mariner 9, will concern scientists for many years unless superceded by Mars-lander data. Each new discovery answers some questions yet spawns many more. The engineering disciplines are likewise impacted by the rapidity of innovations and their application to manifold and often diverse systems. The nature of management and of administration of large research, development, and operational programmes seems to dictate the need for fairly comprehensive histories for valid analysis [20].

Histories of national space programmes: These ultimately must be undertaken and will necessarily involve the full integration of many monographs and the work of many historians. National space efforts are inherently enmeshed in the international environments of science, technology, and policy.

Assessing, as we have briefly here, the overall spectrum of the full history of rocket technology and space exploration seems valid in a process of defining worthy and manageable parts of this massive history for precise scholarship. Obviously no attempt was made here only to be dogmatic since the history of rocket technology and space exploration is in a primitive gestation period. The collection of documents and data, as well as the research for the preliminary histories, is no small task. A critical review of substantive historical works as they appear, as well as rejection of superficial attempts, must be an essential feature of historical scholarship henceforward.

In Conclusion

Can historians of today aspire to become truly objective and dispassionate scholars as the Greek historian Thucydides, despite our living in the dynamic environment in which space history has been made? The degree to which we might attain this goal – our methodology and our skills – inevitably

will be evaluated by the judgments of those to come. Contemporary historians therefore serve future historians beyond any immediate reception given to our literary contributions. Accuracy of fact and validity of interpretation, as well as impeccable chronology, documentation, explanation, and generalization, seem the classic hallmarks of historical scholarship whatever the subject and time period involved. So-called 'histories' that are purely commercial or self-seeking – the art of politics by other means or the perpetuation of pre-space-era concepts of the Solar System and man's place in it – surely will not stand the test of time. Space exploration has already stimulated a flood of popular as well as a few serious publications around the world. Historians need be concerned mainly that their works may earn a lasting place as genuine contributions to knowledge about man's past experience.

When the so-called 'space age' began with the launch of Sputnik 1 on 4 October 1957, the U.S. National Advisory Committee for Aeronautics, known as the NACA, formed a Special Committee on Space Technology headed by H. Guyford Stever. It had working groups with chairmen who assumed later prominence: J. A. Van Allen, W. von Braun, W. H. Pickering, W. R. Lovelace and others. Its final report was submitted to NACA's successor, the National Aeronautics and Space Administration (NASA), during its first month of existence in October 1958. In its introduction, the Stever Committee said:

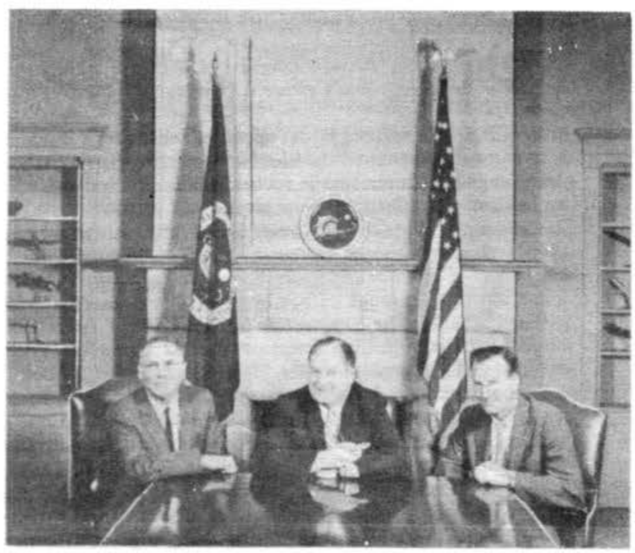
> *Scientifically, we are at the beginning of a new era. More than two centuries between Newton and Einstein were occupied by observations, experiments and thoughts that produced the background for modern science. New scientific knowledge indicates that we are already working in a similar period preceding another long step forward in scientific theory. The information obtained from direct observations, in space, of environment and of cosmological processes will probably be essential to, and will certainly assist in, the formulation of new unifying theories. We can no more predict the results of this work than Galileo could have predicted the industrial revolution that resulted from Newtonian mechanics [21].*

The heroic first phase of man's exploration of his Solar System beyond the environs of Earth has about come to its end. As the telescopes helped men to see the place of the Earth in orbit around the Sun in the 17th century, so rocket propulsion has enabled scientists to test and augment new knowledge received from beyond the cataract of Earth's atmosphere in the 20th century. Now the frontiersmen of the comingled disciplines of the space sciences foretell a wholesale acquisition of new understandings of the meaning of space, time, energy, motion, and life processes in the Universe. Once again the significance of future potentials of space exploration and exploitation does not appear widely accepted by even the majority of thinking men rooted in earthbound affairs. The daily and revolutionary impact of weather, communications and earth resources satellite upon life on Earth is little appreciated. The 'racing car' technology used in Apollo is being supplanted with the 'truck' or 'sky-train' reusable and more economic transportation technology of the Space Shuttle for the 1980's.

In the present era of astronautics, with its tender cosmic philosophy, perhaps a new renaissance of the mind and spirit of mankind on Earth may be in the making: a renaissance sparked as the new geography of Columbus and Magellan, and the new astronomy of Copernicus and Galileo, helped loosen Europe from the Middle Ages and brought forth democratic nation-status; or the new biology of Darwin and the new challenges and wider benefits of the industrial revolution assisted great intellectual stimulus for the conscious man in the late 19th century, as well as humanitarianism and technological mobilization of the leading industrial nations during two world-wide wars in the first half of the 20th century. The impact of astronautics since the Sputnik era, however, has assumed a historical trajectory of its own. Although mankind has vicariously now been to the Moon with the Apollo missions, the space challenge seems destined to continue to capture curiosity and attention into the foreseeable future.

As in most man-made ventures, there was a small band of zealous prophets who anticipated a science and technology of rocketry and astronautics that they themselves could not achieve or fully explain. So also the new cosmology envisioned by Tsiolkovskiy, Goddard, and Oberth, nurtured by rocket and interplanetary societies, and carried on by others, suddenly expanded in the mid-twenties to encompass our whole Solar System and beyond. The gospel of the new space disciplines is not pure theory. Space mobility has sown the seeds for a dynamic revolution in man's basic comprehension of Universal nature and his drive for the exploration of accessible reality. New data returned from the surface of the Moon and the nearby planets may serve as Rosetta stones for comprehending the physical history of the Earth. Future prospects in understanding the atmosphere of Mars and Venus, influenced by the same environment, could help unlock clues of central importance to better comprehending the mechanics of our Earth's life-giving environment. And the charting of the Universe is really under way.

Space undertakings now seem limited mainly by the pace of men's willingness to undertake them. The new and valid



The first Administrators of NASA. Dr. T. Keith Glennan (centre), first NASA Administrator (1958-60); Dr. Hugh Dryden (left), Deputy Administrator; and Mr. Richard E. Horner (right), Associate Administrator.

National Aeronautics and Space Administration

National Aeronautics and Space Administration

President John F. Kennedy and Dr. R. Gilruth, Director of NASA Manned Spacecraft Center at Houston, Texas, inspect model of Apollo command module on 12 September 1962. Speaking at Rice University later the same day, President Kennedy stated that the United States means 'to become the world's leading space-faring nation. We sail on this new sea because there is new knowledge to be gained, and new rights to be won, and they must be won and used for the progress of all people'.

view of our 'blue planet' from above the 'dirty beach sand' of the Moon, described by the Apollo 8 crew in December 1968, certainly served to trigger man's precious appreciation for his unique 'Spaceship Earth' [22]. Foretelling what the future may bring is not the task of historians. But what has happened during the first decade-and-a-half of man's era of space mobility – for his instruments and for himself – shaped a limitless challenge, a process now awaiting the careful attention of many more competent historians.

REFERENCES

1. Cf. Otis D. Duncan, 'An Appreciation of William Fielding Ogburn', *Technology and Culture*, **I** (Winter, 1959/1960), pp. 94-99.
2. In the US several seminal books appeared which are considered to have greatly expanded the number of people, particularly young engineers, interested in rocket technology and space exploration. Significant of these are:
G. E. Pendray, *The Coming Age of Rocket Power*, (New York: 1945), whose manuscript was read by R. H. Goddard; Willy Ley, *Rockets, Missiles and Space Travel*, (New York: 1949), which was to go through 21 printings and 4 revisions by 1970; Arthur C. Clarke, *The Exploration of Space*, (New York: 1951), a Book-of-the-Month Club Selection in 1952; Cornelius Ryan (ed.), *Across the Space Frontier*, (New York: 1953), a book version of papers by J. Kaplan, W. von Braun, H. Haber, W. Ley, O. Schacter, and F. L. Whipple (given at the First Conference on Physics and Medicine in Outer Space, San Antonio, Texas, and published in *Collier's* magazine in 1952) that led to the Walt Disney movie 'Man in Space' in 1954. Beyond the early writings of Tsiolkovskiy, Goddard, Oberth, and Esnault-Pelterie were several sets of works that became classic volumes: N. A. Rynin, *Interplanetary Flight and Communication*, U.S.S.R.: 1928-32); *Die Rakete: Zeitschrift des Vereins fur Raumschiffahrt*, a magazine of the Verein fur Raumschiffahrt edited by J. Winkler and W. Ley, 1927-29; *Jet Propulsion*, (1930-32), *Astronautics*, (1932-45), and *Journal of the American Rocket Society*, (1931-62); P. E. Cleator (ed.), *Journal of the British Interplanetary Society*, (1934-39); and A. Ananoff, *L'Astronautique*, (Paris: 1950), who early contacted Tsiolkovskiy and was one of the founders of the International Astronautical Federation. These would seem to be among the more stimulating works.
3. Cf. V. N. Sokolsky, *Russian Solid-Fuel Rockets*, (Moscow: 1963), translated by NASA (TT F-415). Few gunpowder rocket developers, if any, other than H. Ganswindt (1856-1934) had any genuine space technology thoughts. Jules Verne's *Voyage to the Moon*, (1865), as also the works of H. G. Wells and K. Lasswitz, was inspirational to K. E. Tsiolokovskiy, R. H. Goddard, and H. Oberth so that science fiction should not be ignored in the prehistory of astronautics. Cf. A. C. Clarke, 'Imaginary Worlds', *The Promise of Space*, (New York: 1968), pp. 3-12.
4. C. McL. Green and M. Lomask, *Vanguard: A History*, (Washington, D. C.:1970), pp. 18-39; Cf. L. V. Berkner and H. Odishaw (eds.), *Science in Space*, (New York:-1961), pp. 34-37; Wilmot N. Hess (ed.), *Introduction to Space Science*, (New York: 1965).
5. The International Committee on Space Research (COSPAR) was a direct continuation of the IGY and it has functioned very effectively. Cf. A. Frutkin, *International Cooperation in Space*, (New York: 1965) and 'International Cooperation in Space', *Science*, **169**, (24 July 1970), pp. 333-39. On international cooperation also see E. M. Emme (ed.), *Statements by Presidents of the U.S. on International Cooperation in Space: A Chronology, 1957-1971*, (U.S. Senate Doc. No. 92-40, 1971).
6. On the U.S. creation of the National Aeronautics and Space Administration in 1958, see R. L. Rosholt, *An Administrative History of NASA, 1958-63*, NASA SP-4101 (Washington, D.C.: 1965), pp. 3-17; and L. S. Swenson, J. M. Grimwood, and C. C. Alexander, *This New Ocean: A History of Project Mercury*' NASA SP-4201 (Washington, D.C.: 1966), pp. 77-106.
7. M. W. Rosen, 'Big Rockets', *International Science and Technology*, **I**, (December 1962), pp. 66-71.
8. For example, see Hugh L. Dryden, 'National Significance of the Augmented Program of Space Exploration', *Aerospace Historian*, (January 1962), pp. 52-59; J. E. Webb (Administrator of NASA, 1961-68), *Space Age Management: The Large-Scale Approach*, (New York: 1969); and R. C. Seamans, Jr. (Associate Administrator of NASA, 1960-67), *Action and Reaction*, Minta Martin Lecture for 1969, (Cambridge, Mass.: 1969).
9. Among those which should be noted in this regard are the programmes of respective history committees of the International Academy of Astronautics, the American Institute of Aeronautics and Astronautics, the American Association for the Advancement of Science, the British Interplanetary Society lectures, and the scientific conferences of the Institute of History of National Science and Technology in the Academy of Sciences U.S.S.R. Historians presenting research papers also appear on the above programmes. In the U.S., historians present occasional papers on aerospace history at their professional historical society conferences, as engineers and scientists also present memoir papers at their respective professional meetings. The National Space Club sponsored the annual Robert H. Goddard Historical Essay Competition in 1962 and the American Institute for Aeronautics and Astronautics created the History Award in 1967 for book-length manuscripts.
10. Lewis Mumford, *The Myth of the Machine*, (New York: 1970), p. 7. It seems unfortunate that Mr. Mumford may have been misled by the consistently sensational depth of the news media instead of availing himself of some of the critical historical scholarship already available.
11. E. M. Emme, 'NASA', *Fourth National Colloquim on Oral History Proceedings*, (New York: 1970), pp. 8-12.

12. I. A. A. History Symposia are annually summarized in *Technology and Culture*, quarterly of the Society for the History of Technology. English language proceedings for the first 2 symposia are being edited for publication by F. W. Durant of the Smithsonian Institution and the 3rd and 4th symposia by E. M. Emme. The first Russian language volume has already appeared as A. A. Blagonravov and V. N. Sokolsky (eds.), *From the History of Rockets and Astronautics*, papers of the XVIIIth IAF Congress, Belgrade, 1967 (Moscow: 1970). Cf. E. M. Emme, 'International History of Rocketry and Astronautics Symposium: Constance, West Germany, October 1970, *Technology and Culture*, **12**, (July 1971), pp. 477-486; R. Cargill Hall, 'Fifth International Symposium on the History of Rocketry and Astronautics, Brussels, Belgium, September 1971,' *Technology and Culture*, (forthcoming).
13. Marvin Barrett (ed.), *Survey of Broadcast Journalism, 1969-1970*, (New York: 1970), pp. 3-4.
14. Cf. N. A. Rynin, *Interplanetary Flight and Communication*, **III**, 9 (Leningrad: 1932; in English as NASA TT F-648, 1971), pp. 101-198; A. Ananoff, *L'Astronautique*, (Paris: 1950); W. Ley, *Rockets, Missiles and Space Travel*, (New York: 1961), Bibliography, pp. 516-42; M. Benton, *The Literature of Space Science and Exploration*, (U.S. NRL: 1958); F. I. Ordway, *Annotated Bibliography of Space Science and Technology, 1931-1961*, (Washington, D.C.: 1961); A. Renstrom, 'Bibliographical Note', E. M. Emme (ed.), *The History of Rocket Technology*, (Detroit, Mich.: 1964), pp. 285-308; United Nations, *International Space Bibliography*, (New York: UN 66 I 21, 1966); and K. M. Dickson, *History of Aeronautics and Astronautics: A Preliminary Bibliography*, (NASA, 1968).
15. NASA has found general and programme chronologies a useful beginning which also provide, when published, an available reference. Cf. E. M. Emme, *Aeronautics and Astronautics: An American Chronology of Science and Technology in the Exploration of Space, 1915-1960*, (Washington, D.C.: NASA, 1961), followed by annual volumes, *Astronautics and Aeronautics, 1963-1970*, NASA SP-4004-8, 4010, 4014, 4015, (Washington, D. C.: 1964-1972). NASA programme chronologies include *Mercury*, NASA SP-4001, (Washington, D.C.: 1963), *Gemini*, NASA SP-4002, (Washington, D.C.: 1969), *Apollo Spacecraft*, **I**, NASA SP-4009, (Washington, D.C.: 1969), and *Ranger*, JPL/HR-2 (Washington, D.C.: 1971). The. I.A.A. has just initiated a chronology of international space events for 1970, being edited by R. Cargill Hall of the Jet Propulsion Laboratory, to be published by *Astronautica Acta*.
16. Cf. T. von Karman, with Lee Edson, *Wind and Beyond* (Boston: 1967), founder of the Jet Propulsion Laboratory at the California Institute of Technology, Pasadena, California. His papers are located at the Caltech Library.
17. See translated works of K. E. Tsiolkovskiy (NASA TT F-236-238) and E. C. Goddard and G. E. Pendray (eds.), *The Papers of R. H. Goddard*, 3 vols. (New York: 1970). The personal and official papers of the late Hugh L. Dryden are now being collected by Richard Smith of the Johns Hopkins University Library; copies of official papers of most NASA Administrators are found also in the respective Presidential libraries. The NASA Historical Archives and the library of the Smithsonian's Air and Space Museum have special biographical collections.
18. Representative U.S. non-space examples are: Rex Cochrane, *Measures for Progress: A History of the U.S. Bureau of Standards*, (Washington, D.C.: 1966); R. Hewlett and O. E. Anderson, *This New World, 1940-46*, and R. Hewlett and F. Duncan, *Atomic Shield, 1947-52*, (Vols. 1 and II of the History of the Atomic Energy Commission; University Park, Pa.: 1958, 1969); T. A. Sturm, *The USAF Scientific Advisory Board: Its First Twenty Years, 1944-1964*, (Washington, D.C.: USAF Office of History, 1967); and A.B.Christman, *Sailors, Scientists, and Rockets*, (Vol.1 of the History of the Naval Weapons Test Center, China Lake, California; Washington, D.C.: 1971). NASA has published only one major laboratory history, E. P. Hartman, *Adventures in Research: A History of the Ames Research Center, 1940-65*, NASA SP-4302, (Washington, D.C.: 1970), but other NASA Center histories are underway to provide another cut beyond programme and overall histories of the full NASA history.
19. Cf. L. S. Swenson, J. M. Grimwood, and C. C. Alexander, *This New Ocean: A History of Project Mercury*, NASA SP-4201 (Washington, D.C.: 1966), and C.McL. Green and M. Lomask, *Vanguard – A History*, NASA SP-4202, (Washington, D.C.: 1970).
20. Cf. M. M. Link, *Space Medicine in Project Mercury*, NASA SP-4003 (Washington, D. C.: 1965); W. R. Corliss, *NASA Sounding Rockets*, NASA SP-4001, (Washington, D.C.: 1971). Example of a general disciplinary history would include R. E. Marshak (ed.), *Perspectives in Modern Physics*, (New York: 1967).
21. NACA/NASA, Special Committee on Space Technology, 'Recommendations Regarding a National Civil Space Program', 28 October 1958, p. 2.
22. Barbara Ward's *Spaceship Earth*, (New York: 1966) presented her thesis on the impact of science on society for the survival of 'the crew of Spaceship Earth' prior to the Apollo missions. Adlai Stevenson, former U.S. Ambassador to the United Nations, however, referred earlier to the Earth as a 'spaceship' in a speech given shortly before he died in 1965: 'We travel together, passengers on a little spaceship, dependent on its vulnerable reserve of air and soil; all committed for our safety to its security and peace; preserved from annihilation only be the care, the work, and, I will say, the love we give our fragile craft'. Speech was given to the 39th Session of the U.N. Economic and Social Council, Geneva, Switzerland, 9 July 1965. U.S. Department of State, *Press Release* (170), 9 July 1965, p.15. Also see planetary planning works of Buckminster Fuller, *Operating Manual for Spaceship Earth*, (Carbondale, III; 1969), and 'Vertical to Live. Horizontal is to Die', *American Scholar*, **39**, (Winter 1969-70), pp. 27-37.

MILESTONES *[Continued from page 401.*

Aug

19 Skylab astronauts observe birth of tropical storm Brenda which struck Yucatan peninsula in Mexico on night of 18 August.

20 Skylab astronauts photograph tropical storm Brenda as it moves towards east coast of Mexico through Tamico and Veracruz.

17 Mars 4, Mars 5, Mars 6 and Mars 7 by mid-day (Moscow time) are respectively 8,770,000, 7,420,000, 4,110,000 and 2,760,000 km from Earth. All trajectories are within pre-set limits: all on-board systems functioning normally.

24 Skylab astronauts Dr. Owen Garriott and Jack R. Lousma begin 4.5 hr spacewalk to replace package of six faulty rate-gyros in station's attitude control system and replace film canisters in ATM.

25 At 1201 GMT Skylab astronauts break world space duration record of 28 days 49 minutes set by first Skylab team.

26 Skylab astronauts pass halfway mark of their scheduled 59 day mission. Spider 'Anita', exchanged for 'Arabella' in experiment container, begins construction of normal circular web.

SMALL EARTH RESOURCE SURVEY ROCKETS*

By T. J. Douglass and P. E. G. Cope†

1. Introduction

Major Earth resource surveys will generally be carried out using satellites or aircraft, but there may be a significant requirement for the use of small rockets in comparatively greater quantities when it is uneconomical to use satellites and when the survey needs to be carried out at higher altitudes than obtained with aircraft. However, if rockets can only be fired from official ranges their use for Earth resources applications will be severely limited.

There is apparently a need for rockets that can be fired from mobile launchers in areas where no range facilities exist. To do this it is necessary that impact areas are predictable to a high degree of accuracy and confidence and that the empty cases can be shown to impact in areas which have an extremely low population density. Impact may be allowed on lightly populated land areas or into the sea, but the chance of hitting a man in the former case or a ship in the latter case must be generally acceptable risk level. One of several alternative schemes for stabilizing the Petrel rocket in order to align Earth resources instrumentation with the ground has been studied in some detail. A simple parachute system is proposed for use with the Skua rocket based on experience gained with meteorological payloads. Both these rockets are shown carrying a camera for photography, but this may be replaced by any other equipment that comes within the space and weight limitations for the payloads.

The standard Petrel and Skua rockets already have an excellent reputation for low dispersion and both may be fired from the same mobile launchers. Only the launcher plates at the rear end of the tube need to be changed to suit the rocket. Skua is normally boosted by one 'Chick' boost motor, 3.5 kg in weight, and the Petrel by three such motors (see Fig. 1). The boost motors are housed in a recoverable assembly which parachutes to the ground close to the launcher.

A 4-Chick boost gives high launch velocities resulting in a significantly lower dispersion than with the standard assembly and this makes the rockets suitable for many Earth resources applications (not only because of their small impact areas, but also because it is desirable to fire the rockets on very accurate paths to ensure that the programmed ground areas are covered). The launch velocities obtained with Petrel and Skua are already far higher than those for any comparable rocket.

2. Description of the Skua and Petrel Rockets

2. 1. Petrel

The Petrel rocket was designed to a specification prepared by the UK Science Research Council and when using the standard 3 motor boost it is able to lift a 18.5 kg payload to an altitude of 140 km. More recently Petrels have been tested using a 4 motor boost to reduce dispersion and to give it the ability to carry a 25 kg payload to 140 km with a maximum acceleration of 75 g. It is this version that is proposed for the high altitude sensing of Earth resources.

The sustainer of the Petrel is the Lapwing solid propellent motor which is 19 cm dia. and 183 cm long and contains an end burning case bonded charge of weight 66.1 kg. giving a mean thrust of 4450 N for a burning time of 32 secs at 15°C.

The boost is made up of 4 solid propellent Chick motors,

Fig. 1. Standard Petrel (left) and Skua rockets.

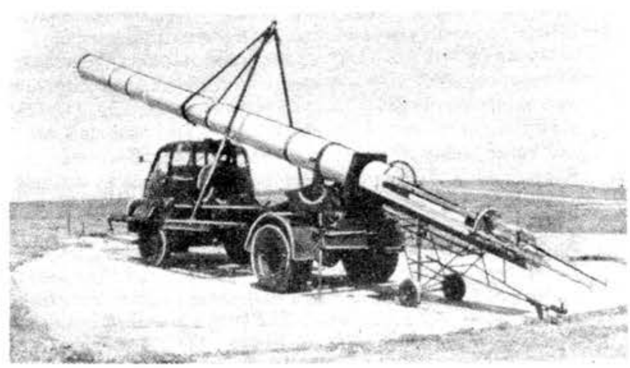


Fig. 2. Mobile launcher showing Skua being loaded.

Bristol Aerojet Ltd.

* *Adapted with permission from Bristol Aerojet Limited, Technical Report No. T.R. 640, Issue 1 July 1972.*

† *T. J. Douglass is senior project engineer of Bristol Aerojet P. E. G. Cope is chief engineer Space Dept., Marconi Space and Defence Systems Ltd.,*

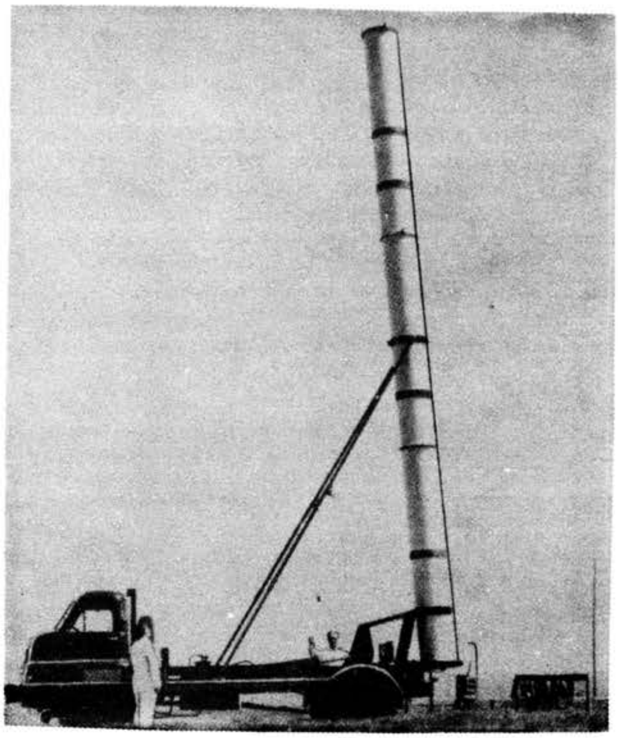


Fig. 3. Mobile launcher elevated.

each with a charge mass of 2.0 kg giving a mean thrust of 20000 N for a nominal 0.21 secs burning time. After burnout the boost assembly descends to the ground on parachutes which has proved to be a very reliable system. The boost carriage hits the ground close to the launcher, after being in the air for 17 seconds. The carriage in which the Chick motors are mounted can be used a number of times; the boost motors can be disassembled and the cases re-used about three times.

Dimensions and Weights Petrel III:

Length overall		383 cm
Length without boost		287 cm
Body diameter		19 cm
Lapwing motor less charge plus fin assembly		27 kg
Charge		66
Nose		25
	Total less boost	118 kg
Boost (filled)		55
	Total with boost	173 kg

2. 1. Skua

The Skua II rocket is able to carry a 5 kg payload to 100 km altitude when the standard one Chick boost is used. The use of a 4-Chick boost while greatly reducing dispersion enables the Skua IV to lift a 5 kg payload to 126 km altitude or a greater payload to lower altitude. A reduced performance can be offered with the short motor Skua I. The apogee may be controlled by the use of drag plates on the nose and fins.

The sustainer of the Skua IV is the Bantam III solid propellent motor. It is 147 cm long and contains an end burning, case bonded, charge of weight 23.6 kg giving a mean thrust of 1700 N and a burning time of 34. secs.

The boost is similar to that for Petrel.

Dimensions and Weights Skua IV.

Length overall		338 cm
Length without boost		242 cm
Body diameter		13 cm
Bantam motor less charge plus fin assembly		12.0 kg
Charge		21.5
Nose (including 5 kg payload)		13
		46.5 kg
Boost (filled)		50
	Total with boost	96.5 kg

3. Payload Stabilisation Systems and Recovery

3. 1. Petrel

The Petrel rocket has sufficient payload capability to carry a simple stabilisation system. This may be developed to meet most Earth resources instrumentation requirements including stabilisation of a 70 mm camera with an effective 800 mm lens system.

The forward 400 mm of the payload is separated from the remainder by means of a despin bearing. This bearing is fitted with slip-rings which provide electrical connections between the spinning and despun portions. When the rocket has left the atmosphere and entered the low dynamic pressure region, at about 80 km altitude, a high torque drive motor is activated to despin the rear section, the residual spin being sensed by means of a single fluxgate magnetometer element mounted in the rear section. The action of the despin motor will, of course, increase the spin rate of the forward section to about 20 rev/sec. Carried in this forward section are a horizon sensor and a gas jet system.

As the forward section rotates, the horizon sensor scans around the spin plane and, if the spin axis is not vertical, detects the Earth/space discontinuity at 2 points on each revolution. By detecting these and by operating the thruster in an appropriate time relationship to them the spin axis of the forward section can be caused to precess towards the vertical. Once the vertical position has been attained, no further horizon crossings will be detected and the jet system will operate only on noise. In this way the spin axis can be brought vertical and maintained in that orientation throughout flight. Since the lower section is roll stabilised with respect to the Earth's magnetic field, the camera system is completely space stabilised. The camera shown in the diagram is designed to scan a series of swathes across the direction of

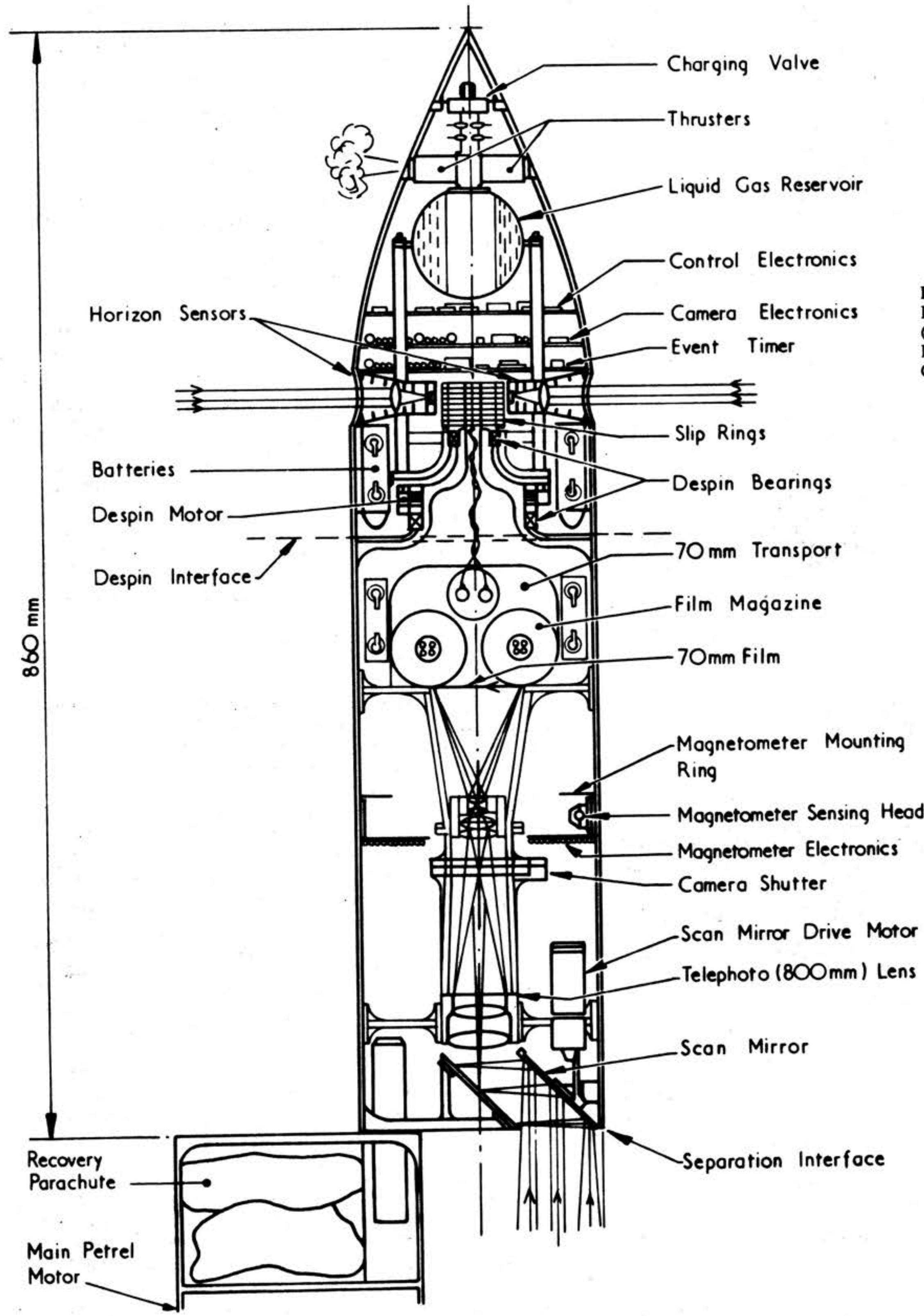


Fig. 4. Petrel Earth Resources Payload (Marconi Space Systems Division's Attitude Control System).

flight so covering the terrain below the rocket trajectory with a pattern of some 200 frames. Calculations of the pointing axis wobble due to dynamic imbalance and control loop noise show them to be within the limits required for use with 70 mm film.

This system is designed for high resolution work with 70 mm film. The same system is clearly applicable to wider field work with similar or smaller infra-red or visible film. Alternative embodiments of the spinning thruster principle could provide a rotating scan suitable for use with longer wave length infra-red detectors like bolometers, pyroelectric detectors or even cooled photon detectors, e.g. mercury-cadmium telluride which are readily adaptable to sounding rocket use and give a very worthwhile improvement in sensitivity over the other types.

A parachute will normally be installed for recovery of the whole or part of the payload. The parachute may be radar reflective or contain a corner reflector to facilitate tracking and location; it may also contain a smoke source. If, however, only the film needs to be retrieved it may be possible to provide a cannister to absorb the forces of impact when the payload compartment is allowed to fall free (thus avoiding wind drift). Alternatively, to remove hazard to persons located within the impact area, the whole of the rocket may be made to descend to the ground on a parachute.

Another arrangement may be to separate the rocket and payload at the end of the payload operational sequence and to deploy a parachute from the payload and recover it in the air with a helicopter.

3. 2. Skua

The 5 in. Skua rocket does not have the payload capacity to carry an altitude control system and the easiest way to point a camera towards a target on the ground is by adjusting the rocket trajectory so that it aligns itself with the target on the down leg soon after apogee.

As with all rockets Skua tends to fall tail first down to a height of 10 km. It has been shown that, after separation from the rocket, a parachute may be deployed which will supply enough drag force to point the payload along the trajectory without significantly modifying this trajectory or making it subject to the influence of wind shears. The system would be usable up to altitudes of 85 km above which height the parachute becomes too large to be housed in the Skua nose. With a payload (cameras, beacons and parachutes) weight of about 9.7 kg, the Skua II boosted with 4-Chicks will reach an apogee of 80 km when fired at 87 deg. At 80 km a 3 metre fine silk parachute will provide a drag of about 0.1 kg which is sufficient force to point the camera steadily after 10 seconds from release. The payload would then closely follow the trajectory of the rocket for about 120 seconds before being disorientated by the drag and carried by the wind. During this time the payload pointing angle, which is a tangent to the trajectory, would vary as trajectory shape from 22 deg. to 9 deg. from the vertical giving 'aiming' points varying progressively from 50 km to 38 km from the launcher. To aim closer than 35 km a launcher angle nearer to 90 deg. is needed, (88.5 deg. Q.E. gives an aiming position of 22 km from 70 km altitude).

The aiming point of the payload may or may not be the aiming point of the camera as the camera may be offset at an angle and when combined with a slow spin will increase the area of coverage.

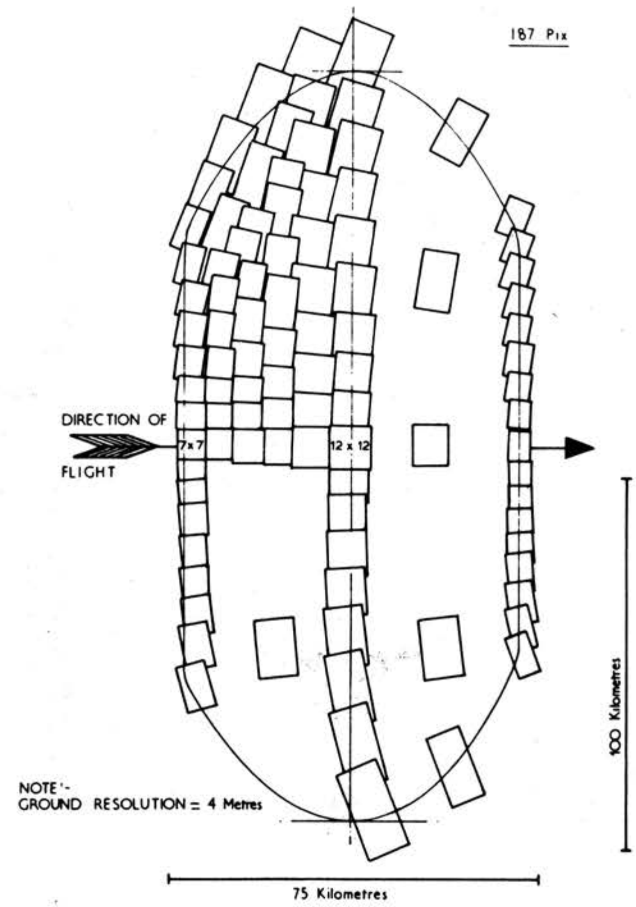


Fig. 5. Earth Resources Petrel Ground Coverage, based on 70 mm film and 800 mm lens.

The likelihood of photographing a given area adequately can be calculated from the number of frames, the camera angle and the spin rate. Spin rate may be reduced at apogee by deployment of a simple 'Yo-Yo' device and through parachute damping.

The parachute required to point the payload is unlikely to be suitable for recovery of the payload because of its very slow rate of descent at the lower altitudes and resulting wind drift. A graph shows altitude versus time where a second 1 metre parachute is deployed after release from the 3m parachute at a 30 km altitude. The total estimated time for descent from 80 km is 21 minutes with this system. Both parachutes may be radar reflective to aid tracking. A beacon which may be visualised as a normal sea rescue transmitter can have its aerial in the shroud lines of the parachute so that it provides a good signal for direction indication during descent and it may have another aerial which erects itself on landing.

If it is desired to photograph a given area the dispersion of the rocket will affect aiming accuracy. At a launch angle of 87 deg. 2σ-wind error gives a 7 km displacement of aiming point. To photograph areas at greater ranges the rocket may be fired to lower apogees so that the higher drag on the parachute will point the camera at greater angles to the vertical.

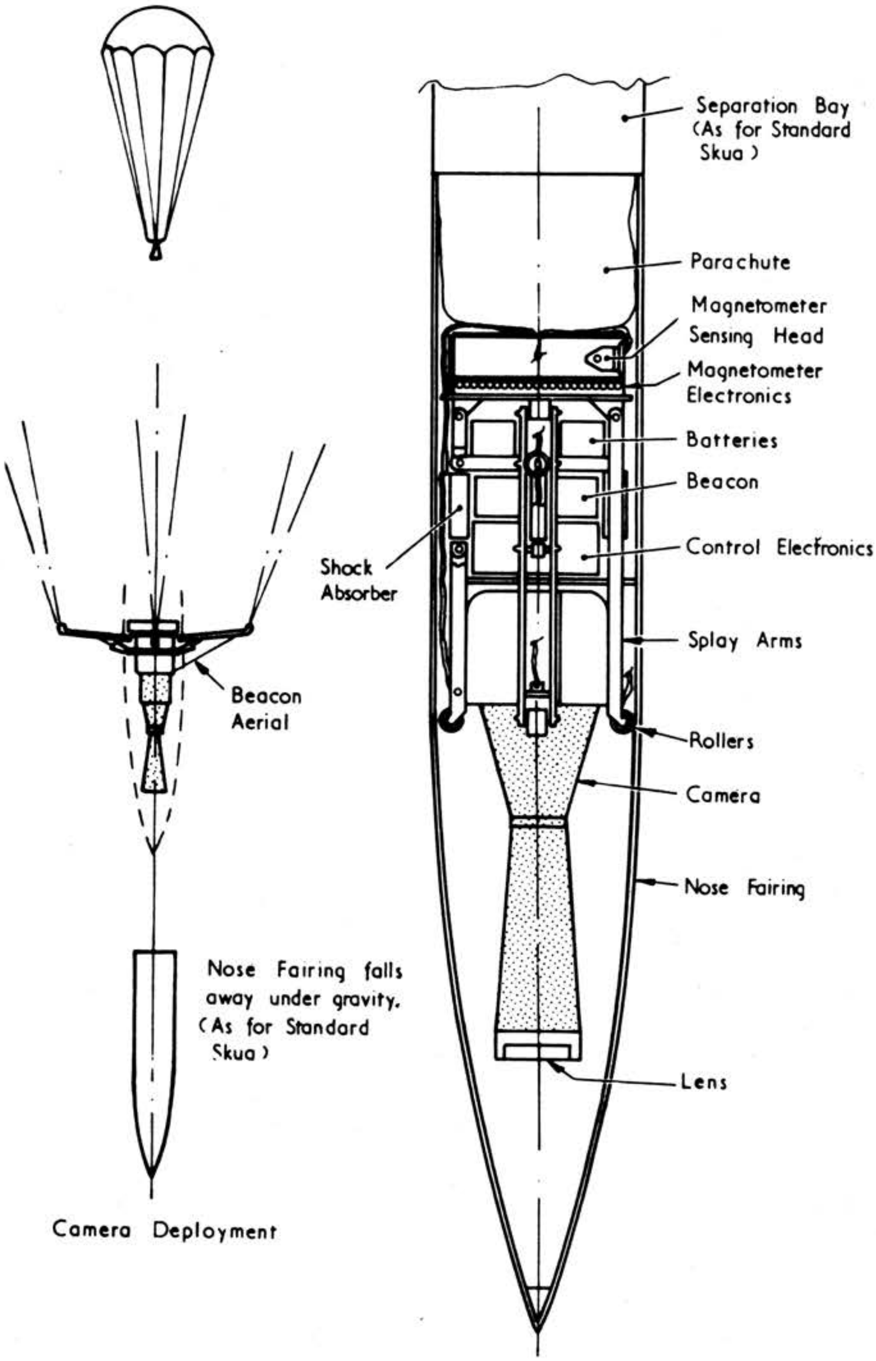


Fig. 6. Skua Earth Resources Payload.

For instance, for a launch angle of 80 deg., a payload pointing angle of 45 deg. is obtained which gives an aiming point 130 km from the launcher which reduces to 75 km at a lower point on the trajectory where the camera angle approaches the vertical.

To obtain longer ranges with a vertical line of sight it would be possible to allow the payload to drift on its parachute under the influence of a predicted wind. High altitude winds are fairly consistent except at known periods when winter westerlies give way to summer easterlies in the northern-hemisphere and vice versa. This technique will be affected by parachute swing and spin. Both swing and spin which are present at medium altitudes are dependent on the design of the parachute and below 25 km altitude the spin rate would be effectively zero and swinging should have ceased.

4. Cost Effectiveness

4. 1. Petrel

The attitude control system for the Petrel rocket has yet to be developed. Although the price per firing of the system

TABLE 1. Earth Resources Petrel III: Performance Data.

Apogee km.	140 km. Max.	134 km.	129 km.
Ranging km/deg.	17.3		
Launch Vel. m/sec.	137	137	137
Wind Effect deg./m/s.	.42	.42	.42
3.72o-Impact Radius km.	26.6	26.6	26.6
300o- " " km.	21.4	21.4	21.4
Range above 80 km (km)	26 km.	42 km.	75 km.
Time above 80 km.(secs)	225	212	202

Table II. Earth Resources Skua: Performance Data

	SKUA I	SKUA IV
Apogee km.	75	80
Ranging km/deg.	8.0	11.8
Launch Vel. m/sec.	205	174
Wind Effect deg./m/sec.	.28	.33
3.720o-Impact Radius km.	8.3	14.5
3.00o- " " km.	6.7	11.7
Payload kg.	2.0	9.1

once in production cannot yet be established it will probably be in the region of £4,000 to £8,000.

4. 2. Skua

Although a payload launched by a Skua rocket may not be expected to give as good a ground coverage as the Petrel system, it is considerably cheaper. The price per firing is expected to be about £2,000 without payload once in production. The cost effectiveness of employing a very small rocket for Earth resources purposes will depend upon the definition and accuracy required. It appears possible that a certain lack of pointing accuracy can be compensated for by taking a comparatively large number of exposures. The ability to photograph areas of the ground within 7 km of that planned appears to be a worthwhile facility. As with Petrel other Earth resources payloads may be installed in place of the camera.

5. Performance

Performance details for the Petrel and Skua rockets are given in Tables I and II and typical trajectories for Petrel III, Skua I (with 4 Chick boost) and Skua IV are illustrated.

For any given payload weight and launch angle the apogee can be controlled by the use of drag plates on the nose and fins of the rocket. This provides a useful technique for cutting down dispersion when the maximum apogee is not required for a given payload.

6. Dispersion

6. 1. General

Wind Error is by far the greatest and the only significant cause of dispersion in the case of the Petrel and Skua rockets

[Continued on page 426.

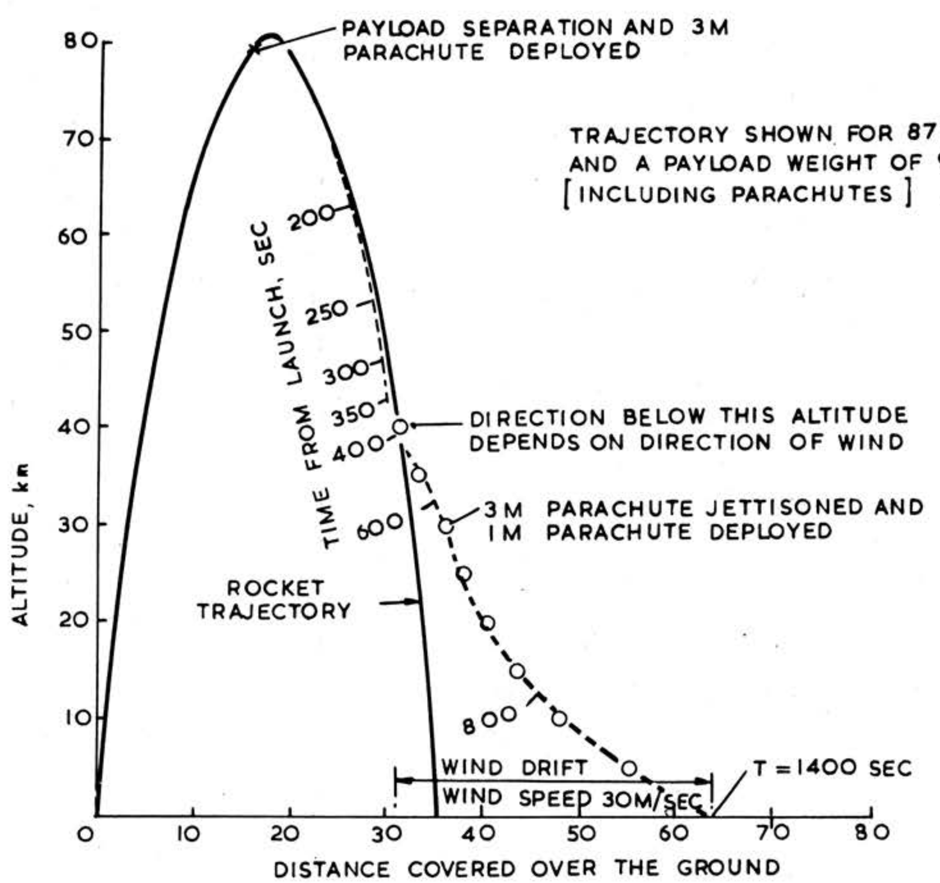


Fig. 7. Skua IV trajectory and payload descent path.

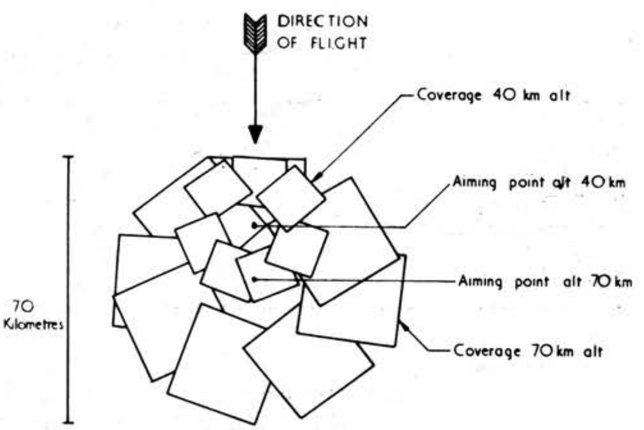


Fig. 8. Earth Resources Skua Ground Coverage using 70 mm film and 200 mm lens. (1) Camera pointing axis is about 16 deg to parachute axis. (2) Diagram illustrates the type of coverage that would be obtained with the exposure of 16 frames at random; possibly up to 200 frames could be exposed between 70 km and 40 km altitude to give a high probability of complete coverage. (3) A 2σ trajectory dispersion displaces the aiming point from 70 km altitude by 7 km.

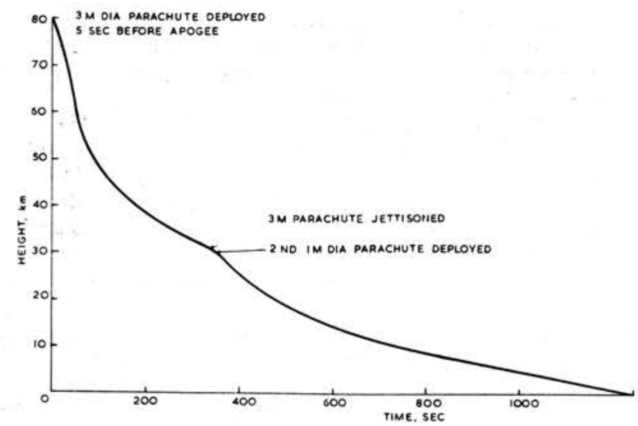


Fig. 9. Height versus time for descent of Skua payload.

All illustrations Bristol Aerojet Ltd.

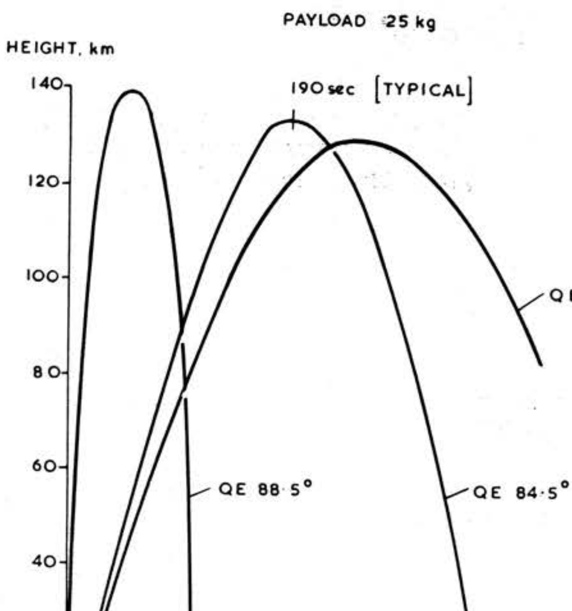


Fig. 10. Trajectories: Petrel with 4 Chick boost (Petrel III).

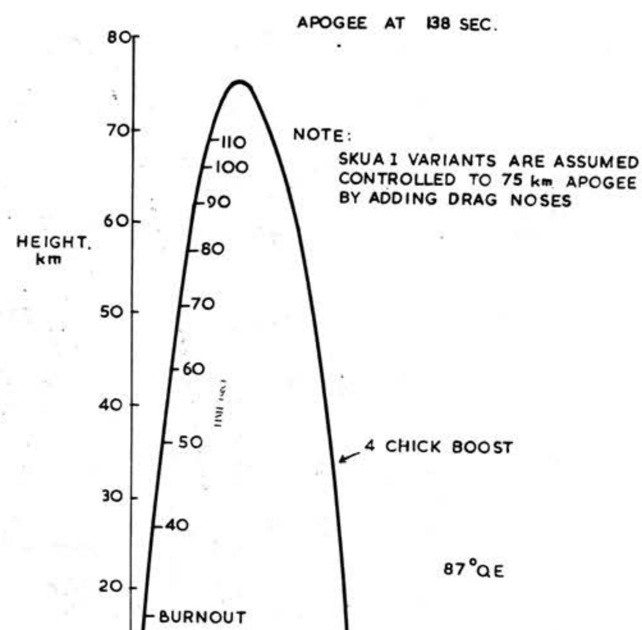


Fig. 11. Trajectory: Skua I with 4 Chick boost, apogee 75 km.

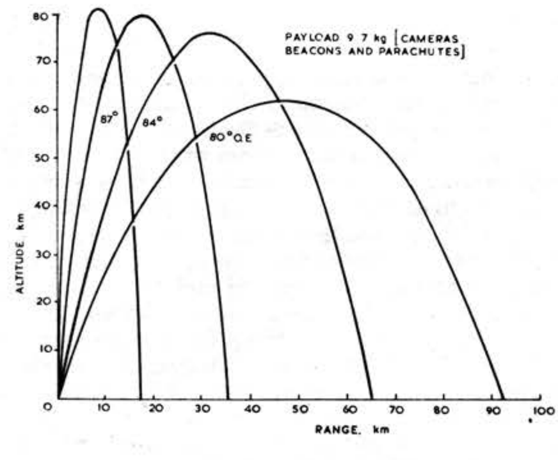


Fig. 12. Trajectories: Skua II with 4 Chick boost (Skua IV).

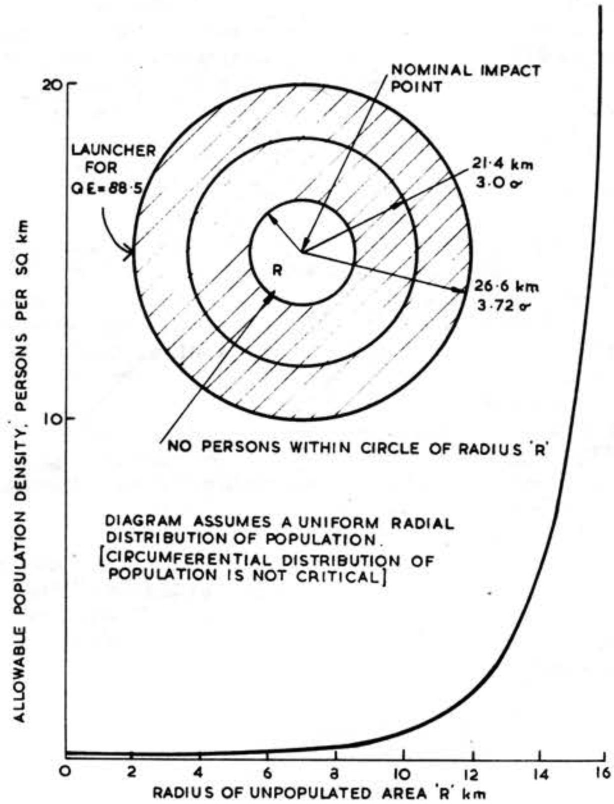


Fig. 14. *Right* Petrel safety trace and allowable population for a 1 in 10 risk of hitting a person on impact (apogee 140 km).

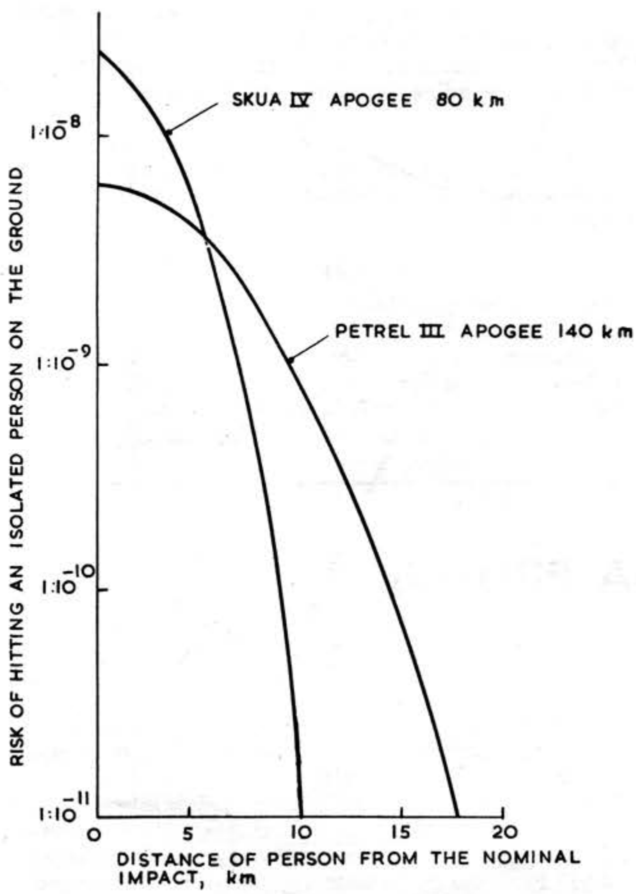


Fig. 13. Risk of hitting an isolated person.

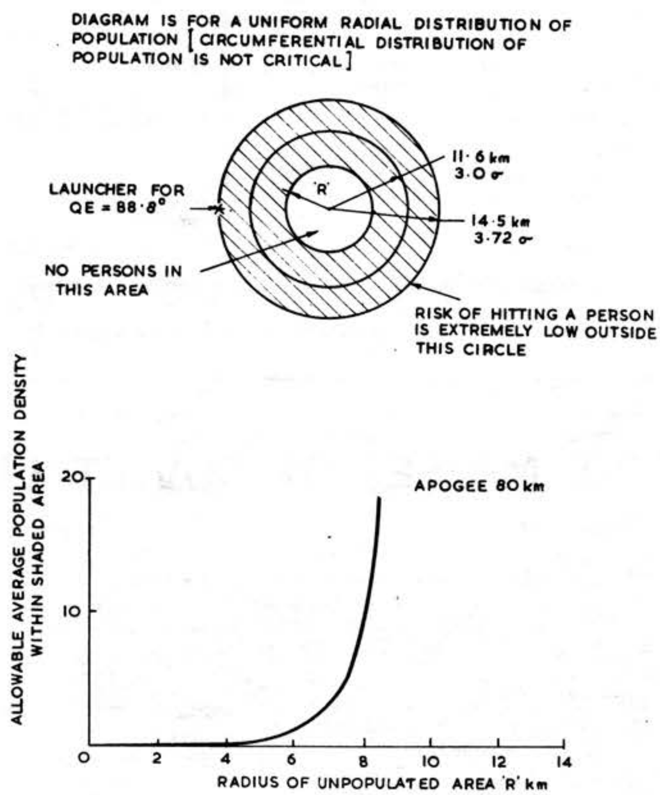


Fig. 15. Skua IV safety trace and allowable population density for a 1 in 10^7 risk of hitting a person on impact (apogee 80 km).

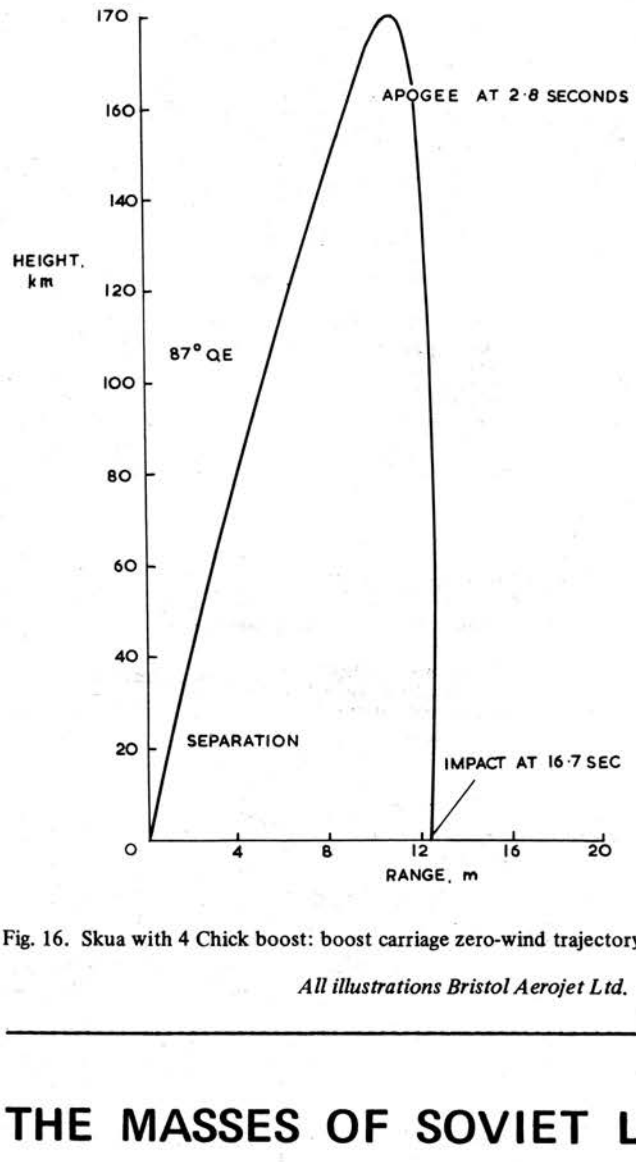


Fig. 16. Skua with 4 Chick boost: boost carriage zero-wind trajectory.

All illustrations Bristol Aerojet Ltd.

with their high launch speeds and low inertias in pitch. It is defined as the error in the mean ballistic wind measured prior to setting up the launcher compared to the actual wind as it affects the rocket's trajectory. The dispersion distance can easily be expressed in terms of the mean ballistic wind (the mean ballistic wind is the uniform wind equivalent to the prevailing wind structure) by multiplying it by a single factor common to each rocket which is mainly dependent on the launch velocity and the rocket inertia. Thus it is important to measure the wind accurately with balloons and theodolites and then it is necessary to apply the rocket wind weighting factors and calculate the launcher setting. An accuracy of 1 m/sec. (1 RMS error) is fairly easily achieveable and the diagrams are therefore based on this. They give a generous picture of the dispersion aspect of a rocket firing.

For convenience the dispersion circles are shown for the highest Q.E. (launch angle) which does not result in a risk of impacting the launch point, but lower Q.E.'s are just as satisfactory. At lower values of Q.E. the range is extended, but the dispersion circles are of essentially the same size.

For a circular gaussian distribution there is a 1 in 10^6 risk of landing outside a circle of radius R = 3.72 sigma and a 1 in 10^4 risk if R = 3.03 sigma.

The risk of hitting a ship of 300 sq. metres is 300 times as great as that of hitting a man.

6. 2. Petrel

Dispersion circles are shown which give allowable population density for the normally accepted criterion of 1 in 10^7 risk of hitting a man assuming him to occupy one square metre with the corresponding distribution on the ground.

6. 3. Skua

Dispersion circles are presented for Skua IV which also show the allowable population density for a 1 in 10^7 risk of hitting a man.

REFERENCES

1. Bristol Aerojet Ltd., Technical Report No. T.R.605, Issue 3, January, 1972.
2. Proceedings of A.I.A.A. Sounding Rocket Vehicle Technology Specialist Conference, Williamsburg, Virginia. 27 February - 1 March 1967. Paper - Operational Range Safety, Lloyd C. Parker NASA, Wallops Station, Virginia.

THE MASSES OF SOVIET LUNA PROBES

By P. S. Clark

The Soviet Union has announced few details of its third generation Luna probe masses. This series began in July 1969, and covers Lunas 15-21 and Cosmos 300 and 305. These latter satellites were Luna probes which failed to escape from their geocentric parking orbits.

The only masses which have been announced in connection with this series are those of Luna 16 on the Moon's surface (1880 kg), of Lunokhod 1 (756 kg) and of Lunokhod 2 (840 kg). The two Lunokhods were carried to the Moon by Lunas 17 and 21 respectively.

Mass of Luna 16

The initial mass of Luna 16 can be calculated by comparison with the Apollo spacecraft.

The mean mass of an Apollo lunar module in selenocentric orbit was about 15100 kg (individual flights deviate from this value) and the mean mass on the Moon was about 6900 kg, or 0.457 times the initial mass. Division of the announced Luna 16 mass of 1880 kg on the Moon by this factor shows the mass of the probe in selenocentric orbit to be about 4100 kg.

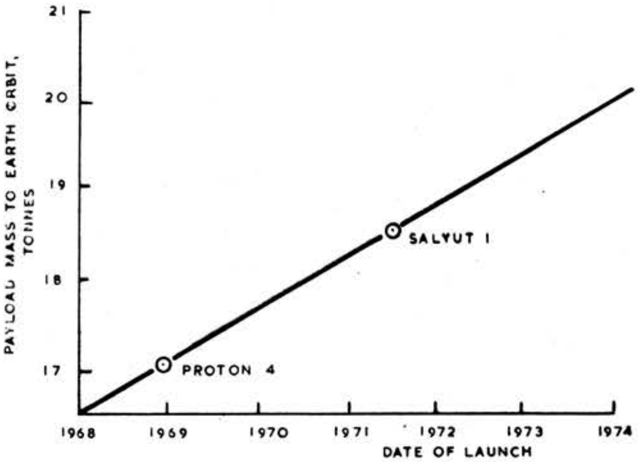
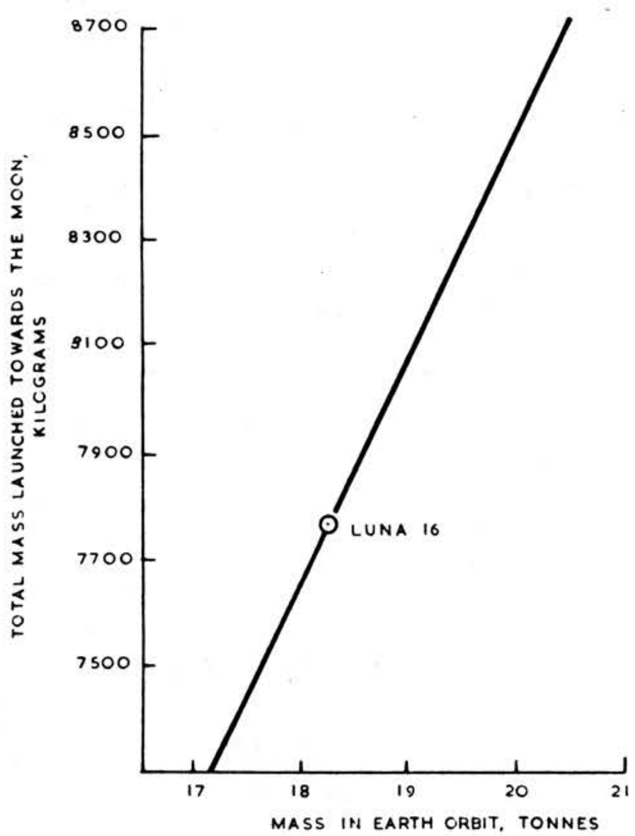


Fig. 1. Plot of launch data against payload capacity.

Fig. 2. Plot of mass in Earth orbit against total mass launched towards the Moon.



A similar calculation for the Apollo service module's selenocentric orbit injection burn indicates that the initial mass during the trans-lunar coast is reduced by 30%. Applying this to the Luna 16 mass of 4100 kg in selenocentric orbit gives an initial mass of 5850 kg for the probe.

Masses of Other Probes in this Series

The third generation of Luna probes are launched by the Proton rocket with an added 'escape stage'. The Soviets have announced the mass of Proton 4 as 17000 kg (this was launched in November 1968), and the Salyut 1 mass has been estimated as 18600 kg. Assuming that the Proton rocket has increased its payload capacity at a uniform rate, a graph can be drawn to connect the launch date and capacity to Earth orbit. A 4000 kg upper stage rocket (the 'Proton Stage') has not been included in this figure. The result is shown in Fig. 1.

The mass of Luna 16 (launched in September 1970) in its parking orbit is seen to be about 18300 kg, and the mass launched towards the Moon (including a 1900 kg 'escape stage') was 7750 kg. Thus the ratio of the mass in a parking orbit to that launched towards the Moon is 2.36:1. Using this proportion a second graph can be drawn, connecting the geocentric orbit mass and the mass launched to the Moon. This is shown in Fig. 2.

Combining the two graphs and the results of the previous section, the masses of the third generation Luna probes were calculated as set out in Table 1.

TABLE 1. Masses in kilogrammes of Third Generation Luna Probes.

Launch Date	Probe	Earth Orbit	Lunar Coast	Lunar Orbit	Lunar Surface
1969					
Jul 13	Luna 15	17500	5500	3850	1770
Sep 23	Cosmos 300	17600	5550	3900	1780 (1)
Oct 22	Cosmos 305	17600	5550	3900	1780 (1)
1970					
Sep 12	Luna 16	18300	5850	4100	1880
Nov 10	Luna 17	18400	5900	4150	1900
1971					
Sep 2	Luna 18	18900	6100	4275	1960
Sep 28	Luna 19	18900	6100	4275	(2)
1972					
Feb 14	Luna 20	19200	6240	4370	2000
1973					
Jan 8	Luna 21	19800	6500	4550	2080

Notes:
1. Remained in geocentric orbit. Full data given simply for easy comparison.
2. Remained in selenocentric orbit.

The accuracy of these estimates can be judged from considering the mission of Luna 21 with Lunokhod 2. Assuming that the mass of a Lunokhod is proportional to the total mass on the lunar surface, it can be seen that the Lunokhod 2 mass is approximately the Lunokhod 1 mass of 830 kg, which compares favourably with the announced Lunokhod 2 mass of 840 kg. Using this method the author was able to predict the Lunokhod 2 mass [to Dr. C. S. Sheldon (in a letter dated 14 January 1973)] before the Soviet Union had released the correct figure.

REFERENCE

1. P. S. Clark, Private Communication to C. S. Sheldon, 14 Jan.1973.

SPACE REPORT

A regular monthly review of Space Events and Technical Trends

NEW GENERATION VENERA

The first stage of the Soviet exploration of the planet Venus and its atmosphere was ended with the experiments of Venera 8. This was revealed by Academician M. Keldysh in his speech at the annual meeting of the Soviet Academy of Sciences last spring, writes Heikki Oja. What are the chances of a second-generation type spacecraft making its appearance during the launch window which opens in October?

When Soviet exploration of Venus began in the 1960's the first three Venera spacecraft that successfully departed from Earth orbit fell silent before reaching their destination. Veneras 4 through 8, however, gave more and more information on the atmosphere beneath the clouds, the last 2 landers sending direct readings from the surface of the planet itself. Thus the goal of the first stage, which was to reveal the composition, temperature and pressure distribution of the atmosphere, was successfully met.

Answering a question in Helsinki last April, Academician Boris Petrov remarked that the second stage of the Soviet exploration of Venus is directed to studying more fully the dynamics of the atmosphere, and the properties and relief of the surface. Since a sufficient amount of light reaches the surface, as Venera 8 found out, it will be possible in future to take photographs of the surroundings of the lander. The composition and structure of the cloud formations, extending down to the height of 35 km, as revealed by Venera 8, are also among the most important objects of research.

What will the second generation Veneras look like? Two years ago the Soviet scientists often emphasized the fact that Mars 2 and 3 were but the first examples of a new generation of planetary spacecraft that will be used to explore several planets of our Solar System. Thus it is expected that the new Veneras will in general construction be similar to the Mars probes.

The current launch window to Venus in October-November this year is of special interest since for the first time in this decade there appears to be a practical possibility for Venus orbiters. The encounter speeds along certain trajectories are so low that a spacecraft with a braking capability similar to Mars 2, can enter an orbit around the planet with a period of 36 hours or even less. The most favourable launch dates fall between 1 and 15 November with the arrivals at Venus in the middle of April; and between 10-25 November with arrivals in the middle of March.

Another interesting feature of this launch window to Venus is that spacecraft can be sent to swing by Venus and encounter Mercury some time later. It will be seen whether the Soviet Union sends a probe or two to accompany the American Mariner 10 on its flight to the innermost planet of the Solar System. The most probable launch dates for the swingby trajectories occur around 5 November, with the encounters with Venus on 6 February and with Mercury on about 1 April; the launch of Mariner 10 has been set for 3 November.

1978 VENUS PROBE

Twenty-two scientists have been tentatively chosen by NASA to provide the experiments for one of two spacecraft destined for Venus in 1978. The group, including one each from France and Germany, was selected from among 72 scientists who submitted proposals in response to a NASA invitation in August 1972.

The Pioneer-class spacecraft is designed to launch four scientific probes toward the surface of Venus and then enter the atmosphere itself, transmitting additional data to Earth until it burns up. An instrument-laden sister craft is scheduled to go into orbit around the cloud-shrouded planet at about the same time

Primary objective of the twin missions is to gather detailed information of Venus' atmosphere and clouds, which could lead to a better understanding of our own atmosphere.

The participating scientists will define experiments dealing with the composition and structure of the Venus atmosphere down to the surface, the nature and composition of the clouds, the circulation pattern of the atmosphere, and the radiation field in the lower atmosphere. Five members of the team will serve as participating theorists, coordinating the various experiments and participating in the analysis of the returned information.

The Pioneer Venus probe mission will utilize a 'bus', a large probe and three small probes. The spacecraft will be spin-stabilised, use solar power, and will weigh about 380 kg (840 lb.) at launch. The trip from Earth to Venus will take 125 days, and will include two or three midcourse manoeuvres.

The probes will be separated from the 'bus' 10 to 20 days before entry. The large probe will carry about 27 kg (60 lb.) of science instrumentation, and provide 60 watts of power. Each small probe will carry 1.5 kg (3 lb.) of instrumentation, consuming 4W of power.

The large probe will take 1½ hours to descend through the atmosphere. The small probes will fall free to the surface. Their mission ends when they reach the surface, about 75 minutes after entry.

The 'bus' will be targeted to enter the Venus atmosphere at a shallow entry angle and transmit data to Earth until it is destroyed by the heat of atmospheric friction. During its descent, information will be transmitted to Earth by telemetry at the rate of 300 bits per second. The large probe will return 100 bits per second.

The spacecraft for the atmosphere probe is scheduled to be launched in May 1978, about three months prior to the launch of the orbiter. They will arrive in the vicinity of Venus within a few weeks of each other in December 1978.

By comparing the atmosphere of Venus, Mars and Earth, it is hoped to construct a better model of Earth's atmosphere for use in predicting long-term changes in climate, as well as short-term effects caused by environmental pollution.

Scientific experiments for the Pioneer Venus orbiter mission will be selected in early 1974.

PHYSICS AND ASTRONOMY APPOINTMENT

Dr. Alois W. Schardt has been named Director of Physics and Astronomy Programmes in NASA's Office of Space Science. He will be responsible for planning and directing programmes that use spacecraft and sounding rockets to explore the Earth's environment, study the Sun, and make astronomical observations.

Deputy Director of those programmes since 1970, he succeeds Jesse L. Mitchell who is retiring after 7 years in the post and 26 years with NASA and its predecessor, the National Advisory Committee for Aeronautics.

Dr. Schardt joined NASA in October 1963 as Chief of Particles and Fields in the Physics and Astronomy Programmes.

He had previously held positions with the Advanced Research Project Agency, Department of Defense; the Atomic Energy Commission's Los Alamos Scientific Laboratory and Brookhaven National Laboratory; and the Calfornia Institute of Technology.

KOHOUTEK'S COMET EXPECTED

A newly found comet as spectacular as anything seen by modern man is approaching the Sun and should be observable well before Christmas. It was discovered last March by the Czech-born astronomer Lubos Kohoutek during a programme of asteroid photography at Hamburg Observatory using the 31-in. Schmitt telescope.

Even the normally cautious Havard astronomer Fred Whipple has been reported as saying that it could be 'the comet of the century' (Halley's comet last appeared in 1910 and is due to return in 1986).

Computer estimates suggest that Kohoutek's comet will pass within 21 million km (13 million miles) of the Sun, well inside the orbit of Mercury. This is bound to cause violent interactions between radiation streaming from the Sun and frozen material in the comet causing an enormous tail to develop which could stretch hundreds of millions of miles across space. A comet's head is generally supposed to be composed of rock particles, dust and ice. As it approaches the Sun, the ices evaporate without melting. The resulting tail always points away from the Sun because of solar radiation pressure.

Kohoutek's comet should be seen in the predawn sky from early November. It should remain visible until late February.

It is hoped to carry out observations of the comet from the Skylab space station.

FUND SUPPORTS SKYLAB STUDENT EXPERIMENTS

A fund of unsolicited cash contributions made to NASA since 1959 by individuals in the United States and overseas has been used to pay for equipment for student scientific experiments on Skylab. Seven student experiments chosen in a nationwide competition among high school students were aboard the first Skylab manned mission. The remaining 12 experiments are being flown on Skylab missions later this year.

The fund of contributions has built up because NASA is authorized by the Space Act of 1958 to accept unrestricted gifts. The amount received to date is $5,548.

In announcing that the fund will be used to pay for the student experimenters' equipment, Dr. George M. Low, NASA Deputy Administrator, said: 'The contributions from many sincere supporters of the space programme will not only be applied toward acquiring scientific data for all mankind but also will be an investment in advancing the future of space exploration by encouraging students to pursue their studies in science and technology'.

The decision to use the gift fund for Skylab student experiment equipment should be particularly gratifying to one teenage contributor who suggested that a 'teenagers for space' programme be started.

In the fund are individual gifts ranging from $1,500, which the contributor sent in three $500 increments, to 35 cents from an eight-year-old boy. The boy wrote a letter to NASA in January 1970 which stated: 'Today I heard you would have to delay some mission because you didn't have enough money. So here is some!' Below his signature he sketched an Apollo command and service module with its rocket engine burning and a lunar module launching from the Moon. Inside outlines of the engine exhaust plumes he taped two dimes and three nickles.

Several contributors have made repeated gifts. A retired Navy chief petty officer in California has sent one day's pay after each manned space flight in memory of his son who was killed in Korea. A young teenage friend of the retired chief has contributed one day's pay from his after school job in a supermarket several times.

A Chicago citizen has sent 23 separate gifts. Three foreign nationals, citizens of the Netherlands, Belgium and Germany, have also contributed. In 1964, an editorial in a national news magazine prompted a naturalized US citizen who immigrated from an eastern European country to send $100. His letter stated that what he cherished most is freedom and wished to be part of the space programme which would mean survival of a free United States.

NASA and the National Science Teachers Association sponsored a national competition for high school students to propose experiments (see *Spaceflight,* February 1973, pp. 57-59). More than 3,400 proposals were received and evaluated by the teachers' association. In March 1972, 25 national winners were announced. Later it was determined that 6 of the winning proposals could be integrated into the Skylab instrumentation and equipment, but the 6 students would work closely with principal investigator scientists whose investigations were very similar to the students' proposals.

WHY SKYLAB SHIELD FAILED

The most probable cause of the meteoroid shield system failure during the 14 May Skylab 1 launch was inadequate venting of the pressure in a tunnel under the shield. The differential pressure buildup in the tunnel, as the vehicle rose through the atmosphere, acted to force the forward end of the shield away from the shell of the workshop and into the supersonic air stream.

An investigation board appointed by the National Aeronautics and Space Administration and chaired by Bruce T. Lundin made this finding in a report to NASA Administrator, Dr. James C. Fletcher.

When the meteoroid shield was torn loose by the supersonic stream, it broke the tiedowns which held one of the two solar array systems on the Skylab Workshop. Later – about 10 minutes into the flight – the solar array 'wing' was completely torn away when it was struck by the exhaust plume of the second stage retrorockets.

Successful operation of the workshop was jeopardised for a time when the remaining solar array would not deploy. A metal strap from the meteoroid shield still attached to the workshop had curled around the wing and penetrated the metal fairing which housed the array.

The mission was saved, however, when astronauts Charles (Pete) Conrad and Joseph Kerwin, acting on the basis of information developed by hundreds of NASA and contractor

personnel on the ground, cut the strap on 7 June. The solar array system was deployed, providing enough power to complete all scientific and technical objectives in a highly successful first manned visit.

A summary of the Investigation Board's report follows:

'At approximately 63 seconds into the flight of Skylab 1 on 14 May 1973, an anomaly occurred which resulted in the complete loss of the meteoride shield around the orbital workshop. This was followed by the loss of one of the two solar array systems on the workshop and a failure of the interstage adapter to separate from the S-II stage of the Saturn V launch vehicle. The investigation reported herein identified the most probable cause of this flight anomaly to be the breakup and loss of the meteoroid shield due to aerodynamic loads that were not accounted for in its design. The breakup of the meteoroid shield, in turn, broke the tie downs that secured one of the solar array systems to the workshop. Complete loss of this solar array system occurred at 593 seconds when the exhaust plume of the S-II stage retro-rockets impacted the partially deployed solar array system. Falling debris from the meteoroid shield also damaged the S-II interstage adapter ordnance system in such a manner as to preclude separation.

'Of several possible failure modes of the meteoroid shield that were identified, the most probable in this particular flight was internal pressurisation of its auxiliary tunnel which acted to force the forward end of the meteoroid shield away from the shell of the workshop and into the supersonic airstream. The pressurization of the auxiliary tunnel was due to the existence of several openings in the aft region of the tunnel. Another possible failure mode was the separation of the leading edge of the meteoroid shield from the shell of the workshop (particularly in the region of the folded ordnance panel) of sufficient extent to admit ram air pressures under the shield.

'The venting analysis for the auxiliary tunnel was predicated on a completely sealed aft end: the openings in the tunnel thus resulted from a failure of communications among aerodynamics, structural design, and manufacturing personnel. The failure to recognise the design deficiencies of the meteoroid shield through six years of analysis, design and test was due, in part, to a presumption that the shield would be 'tight to the tank' and 'structurally integral with the S-IVB tank' as set forth in the design criteria. In practice, the meteoroid shield was a large, flexible, limp system that proved difficult to rig to the tank and to obtain the close fit that was presumed by the design. These design deficiencies of the meteoroid shield, as well as the failure to communicate within the project the critical nature of its proper venting, must therefore be attributed to an absence of sound engineering judgment and alert engineering leadership concerning this particular system over a considerable period of time.

'The overall management system used for Skylab was essentially the same as that developed in the Apollo programme. This system was fully operational for Skylab; no conflicts or inconsistencies were found in the records of the management reviews. Nonetheless, the significance of the aerodynamic loads on the meteoroid shield during launch were not revealed by the extensive review process. Possibly contributing to this oversight was the basic view of the meteoroid shield as a piece of structure, rather than as a complex system involving several different technical disciplines. Complex, multidisciplinary systems such as the meteoroid shield should have a designated project engineer who is responsible for all aspects of analysis, design, fabrication, test and assembly.

'The Board found no evidence that the design deficiencies of the meteoroid shield were the result of, or were masked by, the content and processes of the management system that were used for Skylab. On the contrary, the rigour, detail, and thoroughness of the system are doubtless necessary for a programme of this magnitude. At the same time, as a cautionary note for the future, it is emphasized that management must always be alert to the potential hazards of its systems and take care that an attention to rigour, detail and thoroughness does not inject an undue emphasis for formalism, documentation, and visibility in detail. Such an emphasis can submerge the concerned individual and depress the role of the intuitive engineer or analyst. It will always be of importance to achieve a cross-fertilization and broadened experience of engineers in analysis, design, test or operations. Positive steps must always be taken to assure that engineers become familiar with actual hardware, develop an intuitive understanding of computer-developed results, and make productive use of flight data in this learning process. The experienced 'chief engineer', who can spend most of his time in the subtle integration of all elements of the system under purview, free of administrative and managerial duties, can also be a major asset to an engineering organisation.'

ER SKYLARK FAILS IN SCANDINAVIA

An Earth Resources (ER) Skylark rocket crashed a mile from the launch site at Kiruna, Northern Sweden, on 4 August, after the sustainer rocket failed to ignite. The Skylark survey was part of a research programme sponsored by the Governments of the United Kingdom, Germany and Sweden to assess the usefulness of remote sensing of the Earth's resources by rocket with emphasis on the Northern regions of Sweden, Finland and Norway. One of the main aspects to be studied was the extent and quality of reindeer feed; Lapland's 200, 000 reindeer form an important part of the area's economy. Subjects also to be studied were forestry and vegetation, and geology, soil types and glacier formation.

Professor Hoppe, Chairman of the Swedish Government's Remote Sensing Committee, said: 'We need a complete photographic overview of the vast area where reindeer graze and we believe that Skylark, by using different types of film, will help collect the data we require. Knowledge of the extent and quality of reindeer feed is a very old problem which has concerned people since early this century. The lack of roads and people in the north has made it difficult to obtain up-to-date information. A team led by Project Scientist Dr. L. Wastensson, Natural Geographical Institution at Stockholm University, are engaged on a reindeer feed inventory, reindeer being an important part of the Nordic Lapps' economy'.

The rocket payload contained five Hasselblad cameras, equipped with different lenses and true colour and infra-red film, designed to photograph a circular area over 500 km in diameter from altitudes up to 230 km.

DFVLR, the German Research Authority, supplied the camera bay section of the survey rocket and the Swedish Space Corporation made available their launch range facilities at ESRANGE, Kiruna, assisting with the launch, and in addition were responsible for ground truth studies. The latter were made by small teams, whose fieldwork in certain areas in the region to be photographed, were to be used in comparison

with the rocket's photographic record.

The Department of Trade and Industry in conjunction with the U.K. Procurement Executive engaged BAC Electronic and Space Systems Group at Bristol, who are prime contractors for both Scientific and ER Skylark, to manage the project, prepare the rocket and provide the launch team. The Royal Aircraft Establishment also assisted at launch and acted as design consultants to BAC.

The ER Skylark payload, lost on this occasion, was the modified and refurbished prototype payload first launched and recovered from Woomera, Australia in March 1972 when it proved the concept of photographic Earth resource survey using the long established and usually reliable Skylark.

The rocket, fired from the ESRANGE launcher, was meant to reach an altitude of 230 km. The boost motor burnt for four seconds, and the sustainer should have ignited at six seconds and burnt for 30 seconds, accelerating the rocket to Mach 6 and taking it outside the Earth's atmosphere. The payload section containing the five cameras was meant to separate from the sustainer motor at about 109 km and continue to maximum altitude. After separation the payload should have stabilised to keep the camera pointing downward and they were to be switched on 168 seconds after launch, when photographs would have been taken automatically every 12 seconds whilst nitrogen gas jets stepped the payload horizontally through 38 degrees every 12 seconds.

The payload should have re-entered the Earth's atmosphere at 90 km and at 3 km altitude the parachute system was to return the payload to Earth for retrieval of the film and re-use.

This was the fourth ER Skylark to be launched: in addition to the Australian proving trial, two ER Skylarks were launched in Argentina in March this year, when under a joint UK/Argentine collaborative agreement a photographic survey was made of Central Argentina including that country's main agricultural region. Detailed analysis of the wealth of photographic data continues in the U.K. and Argentina. It is hoped to repeat the Swedish experiment next year.

EXPLORER 48 RESULTS

A NASA satellite designed to observe the little understood gamma radiation in our galaxy and beyond has achieved its primary scientific objective, and the mission has been declared a success. Explorer 48, the Small Astronomy Satellite-B (SAS-B), managed by the Goddard Space Flight Center, carries a Goddard-built gamma-ray telescope (a digitised spark chamber). It is the most sensitive experiment of its kind ever placed in orbit to study gamma ray sources in the sky.

The 186 kg (410 lb.) satellite completed more than six months of successful operation last June before an electrical malfunction occurred and data transmission stopped. An investigation suggested that the problem was associated with the experiment's low voltage power supply.

In declaring the Explorer 48 mission a success, Dr. John E. Naugle, NASA Associate Administrator for Space Science, reported:

'It is clear that even if no further experiment data becomes available, the data already acquired is considered extremely significant since the most promising sky regions have already been surveyed'.

Some of the preliminary results from Explorer 48 observations reported by Dr. Carl Fichtel, Project Scientist at Goddard, include:

(a) Detection of gamma radiation apparently coming from outside our Galaxy which may be of cosmological origin. One theory suggests that the mechanism controlling such radiation comes from the interaction of cosmic rays with interstellar matter. In an expanding universe model, the density of matter was much greater in the past than at present, the radiation produced by cosmic ray interactions reached the satellite from great distances and was distorted during its journey because of the continuing expansion of the Universe. An alternate explanation evolves from the 'big bang' theory of the Universe in which equal amounts of matter and antimatter are created. Matter and anti-matter will separate into regions the size of galactic clusters of pure matter and pure antimatter. At the boundaries of such vast regions, annihilation of matter and antimatter occurs, creating neutral pions which in turn decay into gamma rays, according to this theory.

(b) High energy gamma radiation has been detected from the Crab Nebula. Until these observations, only pulsed energetic radiation had been detected in the Crab.

(c) The centre of our Galaxy has been confirmed to be rich in gamma rays and a detailed map of this radiation is presently being prepared. From a study of the energy distribution of the gamma rays it is now known that two separate mechanisms are responsible for this radiation.

Explorer 48 was launched on 16 November 1972 by a NASA Scout rocket from the Italian-operated San Marco Equatorial Range in the Indian Ocean off the coast of Kenya. It is the second of three spacecraft in the SAS series managed by Goddard. The first SAS satellite, Explorer 42, called Swahili for freedom,was launched from San Marco in 1970, and carried out the most successful studies of celestial X-ray sources ever accomplished by satellite. The third SAS, carrying advanced X-ray experiments, is scheduled for launch in 1975.

Prime contractor for SAS spacecraft is the Applied Physics Laboratory of Johns Hopkins University, Silver Spring, Maryland, U.S.A.

SATELLITE DIGEST – 64

A monthly listing of all known artificial satellites and spacecraft, compiled by Geoffrey Falworth. Information is based on that supplied by the Space Department of the Royal Aircraft Establishment, Farnborough, NASA, Satellite News and BIS sources. For information on the derivation of orbital parameters, abbreviations, etc., see July 1972 issue, p. 262.

Continued from October issue, p. 389.

Name, designation and catalogue number	Launch date, lifetime and descent date	Shape and weight (kg)	Size (m)	Perigee height (km)	Apogee height (km)	Orbital inclination (deg.)	Nodal period (min)	Launch centre, launch vehicle and payload/launch origin
Cosmos 556 1973-25A 6446	1973 May 5.29 8.9 days (R) 1973 May 14.2	Sphere-cylinder 4000?	5 long? 2.44 dia	218 210	225 267	81.33 81.32	88.97 89.31	Plesetsk USSR/USSR (1)
 1973-25C 6630	1973 May 5.29 19 days 1973 May 24	Sphere?	2 dia?	210	255	81.32	89.19	Plesetsk USSR/USSR (2)
Cosmos 557 1973-26A 6498	1973 May 11.02 11.11 days 1973 May 22.13	Irregular cylinder + 4 panels + antenna 18900?	12 long? 4.15 dia?	214 220	243 231	51.59 51.59	89.01 89.90	Tyuratam-Baikonur USSR/USSR (3)
Skylab SL-1 1973-27A 6633	1973 May 14.73 10 years	Cylinder + boom + panel + frame + octagonal cylinder + 4 panels 76175.50	30.78 long 6.61 dia	427	439	50.04	93.18	ETR LC 39A Saturn 5 NASA/NASA (4)
 1973-28A 6640	1973 May 16.69 28 days 1973 Jun 13	Cylinder 3000?	9.75 long 1.52 dia	136 139	352 399	110.49 110.51	89.39 89.89	WTR SLC 4-West Titan 3B Agena D DoD/USAF (5)
Cosmos 558 1973-29A 6645	1973 May 17.56 6 months	Ellipsoid 400?	1.8 long? 1.2 dia?	269	501	70.98	92.26	Plesetsk Cosmos USSR/USSR
Cosmos 559 1973-30A 6647	1973 May 18.46 4.8 days (R) 1973 May 23.3	Sphere-cylinder 4000?	5 long? 2.44 dia	204	325	65.41	89.79	Plesetsk USSR/USSR
 1973-30D 6650	1973 May 18.46 24.87 days 1973 Jun 12.33	Sphere?	2 dia?	211	317	65.39	89.78	Plesetsk USSR/USSR (6)
Cosmos 560 1973-31A 6652	1973 May 23.44 12.8 days (R) 1973 Jun 5.2	Sphere-cylinder 4000?	5 long? 2.44 dia	203 181	314 309	72.85 72.84	89.68 89.41	Plesetsk USSR/USSR (7)
 1973-31D 6663	1973 May 23.44 20.17 days 1973 Jun 12.61	Sphere?	2 dia?	175	297	72.85	89.23	Plesetsk USSR/USSR (8)
Skylab SL-2 1973-32A 6655	1973 May 25.54 28.04 days (R) 1973 Jun 22.58	Cone-cylinder 14152.32	11.06 long 3.90 dia	156 156 359 370 403 415 422 433 425	352 359 372 406 417 425 435 443 440	50.04 50.04 50.04 50.04 50.04 50.04 50.04 50.04 50.03	89.58 89.59 91.81 92.32 92.78 93.01 93.18 93.32 92.17	ETR LC 39B Saturn 1B NASA/NASA (9)
Cosmos 561 1973-33A 6657	1973 May 25.57 11.67 days (R) 1973 Jun 6.24	Sphere-cylinder 4000?	5 long? 2.44 dia	206	295	65.41	89.51	Plesetsk USSR/USSR
 1973-33D 6662	1973 May 25.57 25.61 days 1973 Jun 20.18	Sphere?	2 dia?	206	283	65.39	89.39	Plesetsk USSR/USSR (10)
Meteor 15 1973-34A 6659	1973 May 29.43 500 years	Cylinder + 2 panels + antenna	5 long? 1.5 dia?	853	896	81.22	102.48	Plesetsk USSR/USSR (11)

Supplementary Notes:
(1) Orbital data at 1973 May 5.6 and May 6.4.
(2) Ejected from 1973-25A during 1973 May 13.
(3) Orbital data at 1973 May 12.2 and May 17.0.
(4) Skylab A, first US orbital space station. For a report on this mission see *Spaceflight*, **15**, 334, 1973.
(5) Orbital data at 1973 May 16.8 and May 17.7.
(6) Ejected from 1973-30A during 1973 May 22.
(7) Orbital data at 1973 May 24.1 and May 25.3.
(8) Ejected from 1973-31A during 1973 Jun 4.
(9) Astronauts Charles Conrad, commander, Joseph P. Kerwin, science pilot and Paul J. Weitz, pilot, flew Apollo 116 on a 672 hr. 49 min. mission to occupy and activate Skylab SL-1. For a report on this mission see *Spaceflight*, **15**, 334, 1973. Skylab SL-2 was the 26th US manned orbital flight, 28th US manned space mission and 12th manned Apollo flight. Docked with 1973-27A at 1973 May 25.91, undocked at May 25.95, re-docked at May 26.16 and finally undocked at Jun 22.37. Orbital data at 1973 May 25.55, May 25.56, May 25.65, May 25.74, May 25.77, May 25.80, May 25.84, May 25.86 and May 31.9.
(10) Ejected from 1973-33A during 1973 Jun 3.
(11) 21st operational Soviet meteorological satellite maintains global satellite TV observational capability of Earth's weather, cloud cover, ice and snow fields and thermal emissions from Earth's dayside and nightside surface and atmosphere. Constantly solar-oriented solar cell array panels supply power and gravity gradient stabilisation systems maintain attitude control.

Decays:
Cosmos 260 (1968-115A) decayed 1973 Jul 9, lifetime 1666 days.

Amendments:
Molniya 1H (1968-35A) lifetime is 5.8 years.
Cosmos 501 (1972-54A) lifetime is 20 months.
Meteor 14 (1973-15A) catalogue number is 6392.
Cosmos 553 (1973-20A) lifetime is 9 months.
Telesat 2 (1973-23A) first orbital perigee is 35604, apogee is 35709, inclination is 0.1, period is 1430.7.

SATELLITE SERVICES FOR EDUCATION AND CULTURE:

THE COUNCIL OF EUROPE STUDY

By Dr. J. L. Jankovich

Introduction

There are many space technologists and industry managers among us who recognize the great potential capacity of satellites and wonder whether there will be enough customer demand to justify costly development efforts. On the other hand, educators and other potential users often think that their fields of activity are particular enough to warrant the consideration of facilities dedicated to them alone and question whether this or that type of satellite service would do better for them.

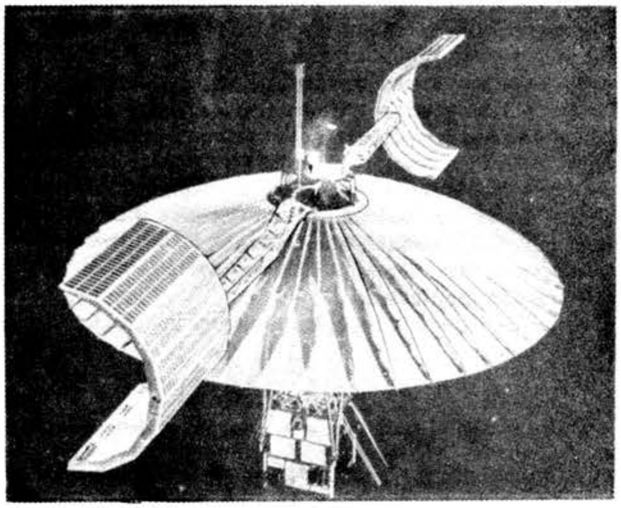
Such diverse views were focused on education in a series of confrontations between representatives of Telecommunication Authorities, space technologists, and educational experts of the Council of Europe. Finally, it was decided to proceed in a systematic way: first, define the problems facing education in Europe, and second, assess the applicable remedies, including satellite technology.

The result of that decision is a broad-ranging study [1] which serves as the basis for my present paper and attempts to answer four questions: (a) What is our study all about? (b) How did we derive our results? (c) What have we learned from our study? (d) What do the study findings mean in our fields of interest?

Study Effort

We concentrated on higher education in 17 Member States of the Council of Europe. As you know, higher education centres around the universities but it also includes post-graduate and other informal studies, professional refresher courses, as well as certain research activities.

The choice of the study subject was due to the great importance of higher education, particularly through its teacher training, for the entire educational system. Thus, in a qualitative way, our study also applies to European education and culture in general. The main set objective was to define the needs of European education for telecommunication facilities in general, and for satellite communications in particular, over the next 10 to 15 years. Another objective was to develop a framework for future



From geo-stationary orbit ATS-F will beam educational TV direct to unique, low-cost receiving stations located in or near schools or community buildings in isolated regions of the Rocky Mountain States where terrestrial TV coverage is not feasible. Cooperating in the experiment with NASA are the U.S. Department of Health, Education and Welfare and the Corporation for Public Broadcasting.

Fairchild Industries

detailed systematic investigation of methods by which advanced technology could help European education and culture.

We addressed ourselves to two groups of audience:

(1) *Educators and administrators*, for whom our study serves as an illustration of a practical method of expressing requirements in a form more or less directly useful for technical agencies; and

(2) *Technical departments*, particularly in PTT, broadcasting and space organizations, as information on recent educational technology developments and as an early warning on educational needs for their services.

Study Sources

The study was conducted under the guidance of a Steering Committee, organized for the specific purpose and composed of educators, specialists in educational technology, technical representatives of the International Telecommunication Union, PTT's and the European Broadcasting Union.

A Europe-wide survey of higher educational institutes and experts, conducted with the help of the Council of Europe Secretariat, provided firm support for our study.

Research and collation of information was carried out by a multi-disciplinary study team where I obtained valuable help from my colleagues at Bell Telephone, Antwerp, and elsewhere in Belgium.

Study Methods

Our investigations used the methods of the systems approach, long-range planning, and management by objectives. Accordingly, we started with a statement of the tasks the higher educational institutes are in general called upon to perform throughout Europe. Next, we assessed the current situation of European higher education and its projections according to prevailing trends. These considerations led to the formulation of the problems facing higher education over the next decade or so.

Comprehensive remedies to the problems were next envisaged and the potential role of educational technology in problem solution was investigated. In response to the outlined role, we then formulated a number of illustrative applications of various interface technologies which could provide a wide range of new educational services and facilities on continental scale.

The considered educational technologies involved such techniques as:

(a) closed-circuit and open-circuit TV;
(b) programmed instruction with audio and visual information;
(c) computer-assisted medical diagnosis and engineering design; and
(d) automatic library information retrieval, etc.

The number of potential users or participants in each of these educational services was then estimated, together with the likely sources of pertinent information. Here, we kept in mind that education involves two fundamental tasks. First, there is the information transmission: a one-way process, in essence, which can be done with the help of technologies. Then, there is the very education or formation itself: a two-way process with feedback paths constantly shifting between student and teacher, where the teacher is irreplaceable.

These considerations helped us to formulate the telecommunication requirements for each educational technology application and to identify such major parameters as the needed network configuration, switching, information flow, and total network capacity. Next came a survey of existing, planned, or feasible European telecommunication facilities, including terrestrial and satellite technologies, and their evaluation with respect to the specified educational needs. Considered were cost figures, initial capital investments, operating expenses with amortization, rental charges, and satellite and launcher development expenses, as applicable. Finally, we identified the types of satellite communication services and frequency bands that appeared suitable to meet the investigated educational needs.

Study Results

What have we learned from our investigations?

In the field of *education proper*, our study has found a broad consensus on the general problems confronting European higher education now and over the coming decade or so. The central problem is the difficulty the universities face when they try to dispense their traditional tasks under the increasingly diversified conditions of today's life. These conditions call for more consideration of the individual than before, at a time when cultural and occupational interests expand rapidly on continental scale.

The rapid growth of student enrolments aggravates the problem: according to conservative estimates, the present European total is expected to more than double within 10 years, and more than treble by 1985.

The central idea of a comprehensive solution could be described as free-choice education. It would provide the individual students and adults with a great flexibility and ease in acquiring new skills, upgrading old ones, and in adapting themselves to the changing conditions of society. In other words, the comprehensive remedy centers around software: the right formulation of educational material and programmes, together with the careful advance planning of their proper introduction and use.

In connection with *educational technologies* we have learned that:

(a) Standard TV broadcast is only one of many possible alternatives; it was not developed in response to any specific educational need but for the primary purpose of one-way information and entertainment.

(b) To choose the best educational technology in a particular situation, the educational effectiveness of the alternative methods should be compared with the pertinent educational objectives and applicable cost figures.

(c) Teachers always form the heart of any educational technology application, to be supported by a network of technicians, studios, libraries of printed and audio-visual material, and a lot of electronic machinery.

(d) New service types are needed, e.g. audio-visual telecommunication with conference call and live feedback

facilities in kind.

(e) *Cost-effective supply of hundreds of educational institutes, many with strongle fluctuating traffic demand, is desirable.*

(f) *The applications of many educational technologies often follow disciplinary lines across state borders, rather than the traditional pattern of major national communication hierachies.*

As for *telecommunications*, our study has found that 3 basic types of facilities could take care of all the surveyed educational technology applications. These are:

(a) *Point-to-point wideband links between educational institutes, studios, libraries, and other sources of educational information, to enable two-way audio-visual and data exchange of large volume;*

(b) *Broadcasting services of audio and visual information to the public in general; and*

(c) *Point-to-point two-way data, audio and visual communication on a selective basis between individuals in their homes and working places on one hand, and the pertinent educational sources on the other.*

The required capacity of these facilities is substantial and may be as much as all the European telecommunication system now planned for 1980. This huge demand appears only, however, when we contemplate educational technology applications for a large geographic area like Western Europe as a whole. The reason is the prohibitively high expense of some of the candidate educational facilities unless shared by many participating countries.

With regard to *satellites* we have found that terrestrial telecommunications could provide the necessary extensions but a hybrid system, using both terrestrial and satellite techniques, would be more cost-effective. A hybrid telecommunication system also would permit the gradual introduction of new educational technologies. Starting with small-scale experimental operation through existing terrestrial facilities, the services could be extended over large areas in step with educational experience and with the availability of satellite communications, if and when they develop in Europe. In the educational source network, for instance, terrestrial links could connect nearby institutes and carry the heavy traffic of pre-assigned routes while communication satellites could provide links upon demand for less frequent connections and between far-away locations.

For broadcasting, semi-direct service through community receivers and wired links to the individual homes appears attractive. Here, broadcasting satellites could help in opening new programme channel allocations in addition to existing and planned terrestrial services. Two-way individual audio-visual communications seems feasible through cable connections with the community receiver centres and nearby university video centres, if properly planned from the start; these centres could be linked by terrestrial or satellite facilities.

Our preliminary cost estimates for a purely terrestrial system and a hybrid one suggest a fascinating idea: the savings resulting from the operation of a hybrid system over 15 years may be enough to finance the European development of the satellite *and the launcher.*

Conclusions

In our immediate fields of interest, the study conclusions suggest the following implications: No satellite services are needed for European education if traditional teaching methods alone are to be used in the future. These traditional methods are already hard pressed to fulfil current needs, and, if left alone, are probably insufficient to meet the more demanding future requirements. New educational technologies could help; their development and use call for continental co-operation along disciplinary lines. They also depend on the availability of effective telecommunication facilities between various institutes, and with individual students both within and without schools.

Satellite communication services could complement terrestrial telecommunications and lead to more cost-effective solutions.

Thus, European education may need:

(a) Fixed communication satellite services, for point-to-point and multiple-access operations, possibly with demand assignment; and

(b) Broadcasting satellite services, possibly in the semi-direct mode of operation, with community receivers and wired links to the individual homes.

Our study conclusions, based on the numerical projections of higher educational needs, merely indicate qualitative and order-of-magnitude factors for the whole field of European education and culture. Yet, even the most cautious preliminary survey leads to results which, in several important points, are significantly different from published official considerations. All this seems to warrant a more detailed study of specific needs in particular educational sectors on European scale for electronic technology aids; telecommunication facilities, and satellite communication services.

The specification of the subject and scope of the follow-up effort is a matter which is now before the educational authorities of Europe.

REFERENCE

1. J. L. Jankovich, 'Satellite Communication Services for Education in Europe', Final Report, April 1971; Council for Cultural Co-operation, Council of Europe, Strasbourg.

Paper presented at the Symposium on 'Space Communications Systems for Education Purposes' of the British Interplanetary Society, University of Southampton, 21 Sep. 1972.

SOVIET GEO-STATIONARY WEATHER SATELLITE

The Soviet Union has announced an intention to launch a meteorological satellite into geo-stationary orbit above the Indian Ocean as part of the international research programme for global atmospheric processes (PIGAP). The main experiment, planned for 1977, will last 18 months.

First part of the research programme includes the existing world network of meteorological aerological stations, the second a system of orbital weather satellites at altitudes up to 1,500 km, and the third geo-stationary satellites. The Soviet Union will orbit one geostationary satellite, the United States two, and Europe and Japan one each.

THE SKYLAB TOUR

By P. J. Parker

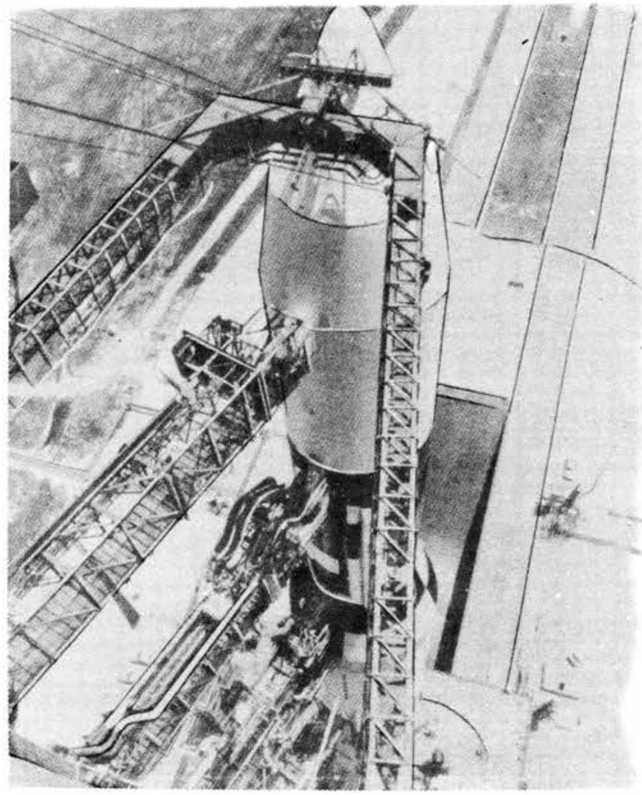
Introduction

On 11 May 1973 a group of BIS members joined the other passengers aboard a giant Laker Airways DC-10 to leave England and savour the delights of sunny Florida and to witness the launch of Skylab, the USA's first manned space station. The tour containing the BIS group was organised by Transolar Travel in co-operation with the BIS and was accompanied by David and Barbara McGee (Transolar) and Len Carter (BIS Executive Secretary). Most of the BIS members among the group went on from Florida to tour NASA Houston and Huntsville centres. The tour was originally scheduled to take in both the Skylab SL-1 (Orbital workshop) and SL-2 (Apollo 1st CSM ferry) launches but, because of problems with the Skylab space station heatshield and solar panel arrays, the party were precluded from witnessing the launch of SL-2 within the 14-days duration of the tour.

Kennedy Space Center

The first major event of the tour was the excursion to the Air Force Eastern Test Range and the NASA Kennedy Space Center on Sunday, 13 May. The highlight of this tour was the impressive sight of the Skylab SL-1 vehicle from the special NASA visitors viewing site, about ¼-mile away. As the vehicle sat quite serenely on the launch pad at LC-39A, it was hard to understand that this gleaming white structure, reflecting against the red mobile launcher tower and the blue Floridian sky would, on the following day, produce a thunderous 7½ million lb. of thrust from its mighty F-1 rocket engines, to insert into Earth orbit a science-fiction dream – the first large manned space station.

A short distance across the marshes the smaller Apollo-Saturn IB vehicle sat enshrouded by the service gantry, as technicians made final preparations for the first manned ferry mission to the Skylab after it had arrived in orbit. This first of three scheduled manned visits to Skylab over an 8-month period was to be responsible for launching astronauts Conrad, Kerwin and Weitz on a mission that would save not only the Skylab space station from near disaster but, perhaps, save the whole NASA manned space programme – besides convincibly demonstrating why Man-in-Space is essential.



The enshrouded Skylab Orbital Workshop and related hardware dominate this view, which includes part of the Skylab I Saturn V rocket and mobile launcher ground support equipment.

National Aeronautics and Space Administration

Before viewing the Skylab vehicles on their respective launch pads, the group visited the Air Force Space Museum. This open air museum featured a Mercury-Redstone rocket and service tower (as used in the USA's first manned space flight in May 1961) surrounded by many different missiles such as Titan II, Snark and Navaho. A mock-up of the X-24A lifting body vehicle is on display and offers some indication of the future when the Space Shuttle vehicle lifts-off from the Kennedy Space Center, to return to Earth in the manner of a powered lifting body.

Besides the space museum the group toured the various launch pads from which many historic spacecraft have been launched, such as Pioneers, Surveyors and Lunar Orbiters, as well as the manned missions of Mercury-Atlas and Gemini-Titan. They also visited the huge Vehicle Assembly Building where the second and third Apollo-Saturn IB's were being prepared for future launches to the Skylab and then, finally, onto the Visitor Information Facility where many models of spacecraft and equipment were on display.

Waiting for Lift-Off

In the early morning of Monday 14 May, there was quite a stir of activity around the group's motel, the Atlantis Beach Lodge, as members began to prepare their photographic equipment in readiness to capture the lift-off of the giant unmanned Skylab space station that was to take place that day. The space station was to ride into space aboard the last of the 'Big-Birds' – the two stage Saturn V. Earlier 3-stage versions of the Saturn V had seen Man leave his earthly home to undertake the first manned explorations and adventures on another celestial body – the Moon – in the Apollo programme. This Monday, however, was to be different. This time Man was going into space to observe and study – using the latest and advanced technologies known to him – his own planetary cradle, his Mother Earth.

The group arrived at the specially provided NASA viewing site, just after 9.30 a.m. local time, among the first of thousands of visitors who attended Kennedy Space Center to witness the lift-off. For nearly 4-hours the group waited and waited and waited, in near-sunstroke heat, for the magic moment when the last of the 'Big Birds' would climb into the sky. During all this time out on LC-39A there was no visible sign of activity, except for occasional white wisps of vented propellents. Then, almost as if unexpected, the voice of NASA announced over the public tannoy system:-

'We are approaching the 1-minute mark in the countdown at this time.'

The Skylab space station was about to be launched!

'T-8 – ignition sequence had started'. An d – yes, there was the orange flame at the base of the giant rocket. An incredible, almost unbelievable show of shear power as the kerosene and LOX ignited in an eruptive glory matched only by the sight of an active volcano. Earlier Saturn launches has seen explorers set out on historic journey's across the spatial void to take Man's first tentative steps on another celestial body of the Universe – the Moon. But this last Saturn-V launch was different. This launch would see the beginning of the realisation of 'Ehrocke's Dream' – the first excavation towards the founding of the three-dimensional civilisation. The dreams of Oberth, Ziolkowsky, von Pirquet, 'Noordung', Smith, Ross, von Braun, Mueller and countless others were about to materialise!

'T minus 5,4,3,2,1,0. And – we have a lift-off! The Skylab lifting off the pad, moving up. Skylab has cleared the tower!' Suddenly, it was as if I was sitting in a circular tunnel with the continuous roar of a powerful express train assaulting my ear drums. The acoustical waves from the giant thrusting first-stage F-1 engines had swiftly travelled the 3½-miles across the marshes from LC-39A and had now begun to pound on my eardrums! It was a sensational and unforgettable experience! As I tilted my head back the last of the 'Big Birds' was ever rising, ever upwards, towards its final nesting ground destined to be at 435 km altitude. For the first few minutes of its flight, a canvas of colour unfolded as the white pinnacle-like Skylab rocket, riding an orange, tapering sheet of flame, merged against the deep blue of the Floridian sky while below it lay the red launch tower squatting amongst the pink-tinted grey billowing clouds of exhaust gases that had been formed by the deluge of cooling water. But, then, like an omen for coming events,the Skylab disappeared into the midst of low clouds.

Post-Launch Excursions

Unfortunately for the group, due to overheating and power problems with the Skylab space station, the lift-off of the first Apollo-Saturn IB vehicle carrying Conrad, Kerwin and Weitz, was deferred until 25 May – to allow emergency procedures to be worked out. After several reorganisations of the tour schedules, the party were happy to relax in the Florida sunshine and to participate on several excursions to well-known and famous tourist attractions such as Disney World and Silver Springs, while an optional tour on Thursday 17 May took many members of the group on a visit to Patrick Air Force Base and Port Canaveral. Here they would be fortunate in viewing a NASA T-38 jet aircraft used by the Skylab astronauts on pre-mission flying schedules and in seeing an Apollo Range Instrumentation Aircraft (ARIA) and modified Boeing aircraft of the Terminal Radiation Programme (TRAP).

To compensate for the loss of seeing the SL-2 manned launch, the group were invited to an American barbeque given by Mary Bubb, an accomplished writer on space flight topics for Reuter and *Time* Magazine. On many of her home walls, she had personally signed space photographs taken by several American astronauts *en route* to the Moon. The barbeque was held to celebrate the launching of a Poseidon missile from a submerged nuclear submarine, some 30-40 miles off-shore. The launch which came precisely on-time at 19.00 local time, was viewed by the group from the sands of Cocoa Beach. They saw, quite clearly, the missile emerge from the submerged submarine and streak away, up and out across the Atlantic Ocean of the Eastern Test Range. The barbeque also acted as a 'farewell-to- Cocoa Beach-and-Cape Kennedy' for the group since, later that evening, they would set out for Florida's Melbourne airport for the short flight down to Miami!

At Miami the group divided into two parties, one to remain at the Royal Biscayne Hotel, Miami while the second party went on to the NASA space centres at Houston and Huntsville. This latter group spent about 1½ days at the Royal Biscayne Hotel along with the other members of the group. For those staying behind, optional tours were available for visits to the famous Seaquarium, Miami Beach and Everglades. Alternatively, one could hire a bicycle and cycle down to the famous Cape Florida lighthouse featured on many USA travel brochures. For those going on to Houston and Huntsville, the delights of the 'millionaires playground' city, Miami, had to be left behind. At 11.30 on Monday 21 May they departed the hotel for the journey to the airport and onward flights to Houston, Texas.

At Houston

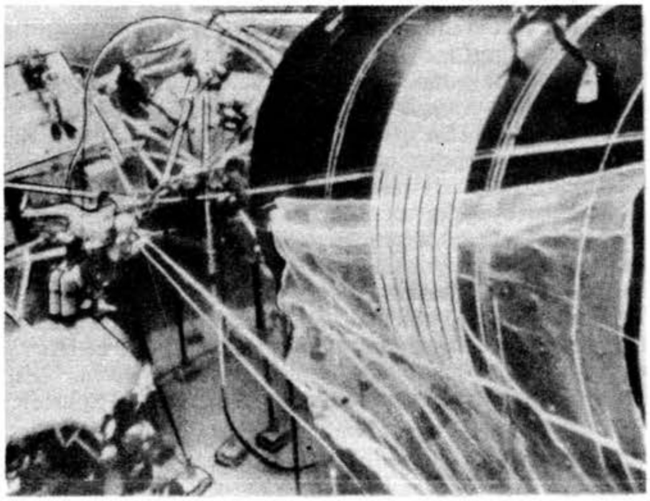
The Houston NASA Manned Space Flight Center (now the Johnson Space Center) is very impressive with its modern buildings nestling in parklike surroundings on the edge of Clear Lake City. It was here, at the Houston space center that men and computers, housed in an almost windowless building called Mission Control, would watch remorselessly over the mission of the entire Skylab space station. The Skylab Operations Room, located within the Mission Control Building, almost had the 'air' of being a sacred shrine to space flight since visitors were escorted, quietly and quickly, into a darkened room known as the 'Viewing Gallery'.

Everything was quiet. Yet this was the Skylab Operations Room well into the 7th day of flight of the space station. Where was the clatter of high speed computer printers, the whirring of magnetic tapes on work stations or the hustle and bustle of mission rescheduling activity in light of the Skylab heating and power crisis? None of this was immediately visible. Then, suddenly, everything was clear. There was no noise from the display consoles located before us because we were divided from them by a sound-proof window! (Fortunately, for the engineers at the consoles, they too were shielded by the windows – from the excited visitors!). Additionally, there was no hectic activity since, at that time, the Skylab was still unmanned and many of the consoles were still inactive.

After the visit to the Mission Operation Control Room (MOCR), the group were shown other buildings of the Houston complex including altitude chambers, centrifuge and the full-scale Skylab mock-ups. An interesting item was the space shuttle pilot's simulation facility. After the formal tour the group were allowed to 'wander around' the Visitor Information Center displays, where full-scale models (and actual flight articles) from the Apollo Programme were on prominent display. These included the Lunar Module and many items from the ALSEP science packages. There was also an impressive display of earlier Gemini equipment and samples of lunar rocks. Following the tour of the Houston Center, on Tuesday 22 May, the group departed their Houston hotel, the Sheraton Kings Inn, at about 13.30 *en route* for the local airport for onward flights to Huntsville, Alabama.

On to Huntsville

The tour of the Alabama Space and Rocket Center, at Huntsville, began at 9.00 a.m. on Wednesday 23 May. This museum is a 'must' for any true space flight enthusiast. It is the only facility in the USA where a full-size Saturn V vehicle, laid horizontally, can be closely inspected! And is that rear



Dr. Joseph Kerwin (*left*) extends a mesh net over a mockup of the Skylab space station inside a neutral buoyancy simulator at the Marshall Space Flight Center. The net simulated an aluminium sunshield, one of three methods studied by the astronauts to solve overheating problems in the orbiting workshop.

National Aeronautics and Space Administration

end of a cluster of F-1's impressive with its intricate 'plumbing'! Anyone standing beneath these huge engines is completely dwarfed by their size and complexity. Even at a smart walking pace, it takes several minutes to walk along the whole length of the Saturn V vehicle and its Apollo payload. Other displays outside at this museum are a full-scale Apollo-Saturn IB (mounted vertically), several missiles and rockets (such as Atlas, Jupiter-C and Mercury-Redstone), early versions of Lunar Roving Vehicles and a simulation, full-size, of the Apollo 11 lunar landing. Although one is impressed by this outdoor display, the indoor exhibition is even more fascinating! Inside there are spacecraft on display from all the major US space programmes, rocket engines of all sizes and several 'walk-through' displays that show and describe future programmes. A particularly interesting exhibit is the wardroom module of the early 33 ft. diameter space station studies. The most exciting aspects of the museum, from a child's point of view (of all ages!), are the hands-on exhibits. These are the computer-type console where one can try his hand at a simulated lunar landing, the gyro chair, the firing of a rocket engine (in a protective case!) and the demonstration of solar cell power.

Following lunch at the Marshall Space Flight Center cafeteria, the group inspected several of this Centre's facilities including laser experiments, solar disc observation tower, the Saturn V stage dynamics simulator and the full-size Skylab backup simulator. The group were also shown around the full-scale mock-ups of the Space Shuttle cockpit, the shuttle General Purpose Laboratory and the large shuttle space telescope payload. Just behind these mock-ups, the engineers connected with the Skylab programme were busily rolling-up the sunshade material that would be transported to the Kennedy Space Center for installation aboard the Skylab-2 Apollo CM in an attempt to salvage the Skylab space station. Because several Skylab astronauts were practicing the new emergency measures, aimed at erecting the sunshade parasol over the Skylab workshop structure, the group were unable to visit the Neutral Buoyancy Tank on Wednesday. However, through the efforts of our guide, Larry Pruitt, we were able to return on early Thursday morning, 24 May, and inspect this huge water tank where many weightlessness space operation simulations have been conducted in support of Apollo and Skylab. Inside the tank were mockups of the Skylab workshop, multiple docking adapter, ATM and a partial Apollo CSM vehicle used the previous day by the Skylab astronauts. In fact, Bean and Garriott of the Skylab SL-3 mission were due in the tank for training on Thursday afternoon.

After the visit to the Neutral Buoyancy Tank, on Thursday morning, the group were directly transported to the airport, at Huntsville, to begin the long trek home to England, after a most successful and enjoyable tour of the three major NASA space centres involved in the important and historic Skylab Space Station programme.

Appreciation from all the group must be recorded to Transolar Travel Limited, especially David and Barbara McGee, for organising this tour in co-operation with the British Interplanetary Society and especially to Len Carter. Grateful acknowledgements should also be extended to the National Aeronautics and Space Administration for providing excellent visitor facilities at all their major space centres and for ever-present kindness and interest in our plans, culminating in our viewing the Skylab launch from a specially provided vantage point.

HAVE YOU CHANGED YOUR BANKERS ORDER?

New Bankers Order forms are currently being sent to every member of the Society using this method of payment.

On receipt of the new form, *PLEASE COMPLETE AND SEND IT TO YOUR BANK* **AT ONCE**.

Dealing with it in this way can lead to a big saving in time and expense, and avoid possible annoyance. Not only will it make sure that your fees are paid at the proper time (you must allow time for the change to be registered and acted upon by your Bank) but it can save *us* a good deal of time in sending out further reminders, besides the thankless task of trying to deal with accounts when only part of the dues are paid.

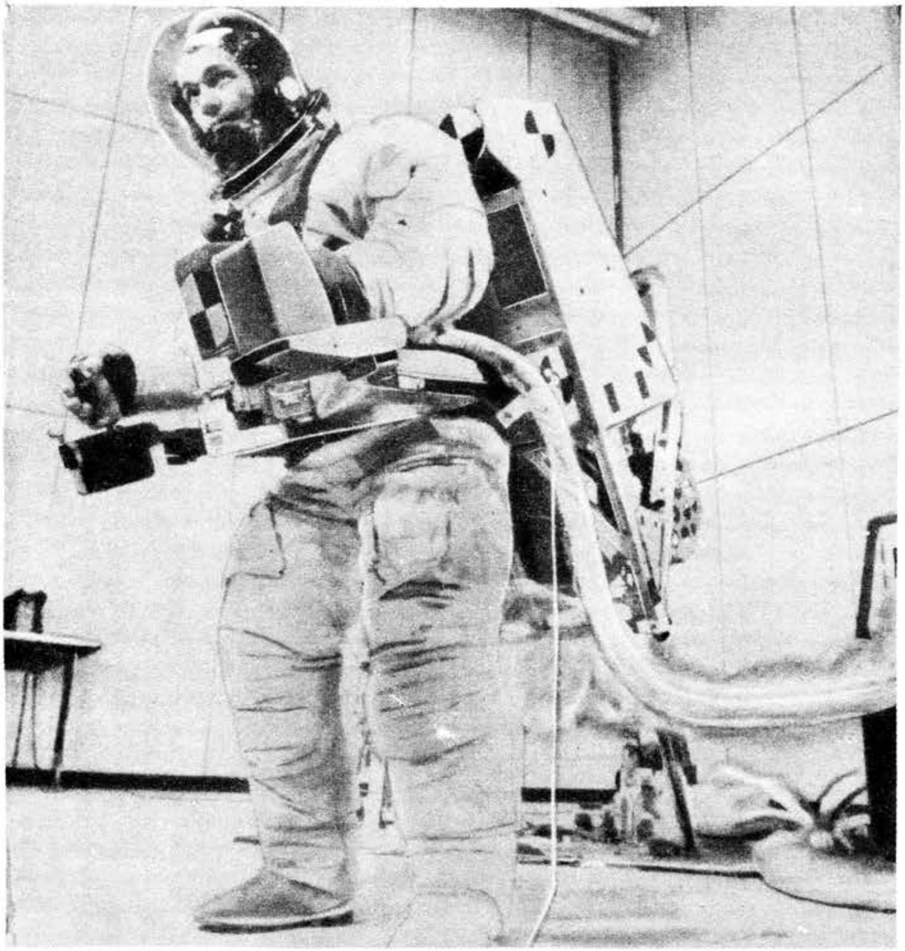
Besides the insertion of the new amount, *it is essential* that your remittance is credited to our new Bankers Order Account. It is only by ensuring that remittances are properly identified and listed (for VAT and other purposes) that troublesome searches and correspondence on queries can be avoided.

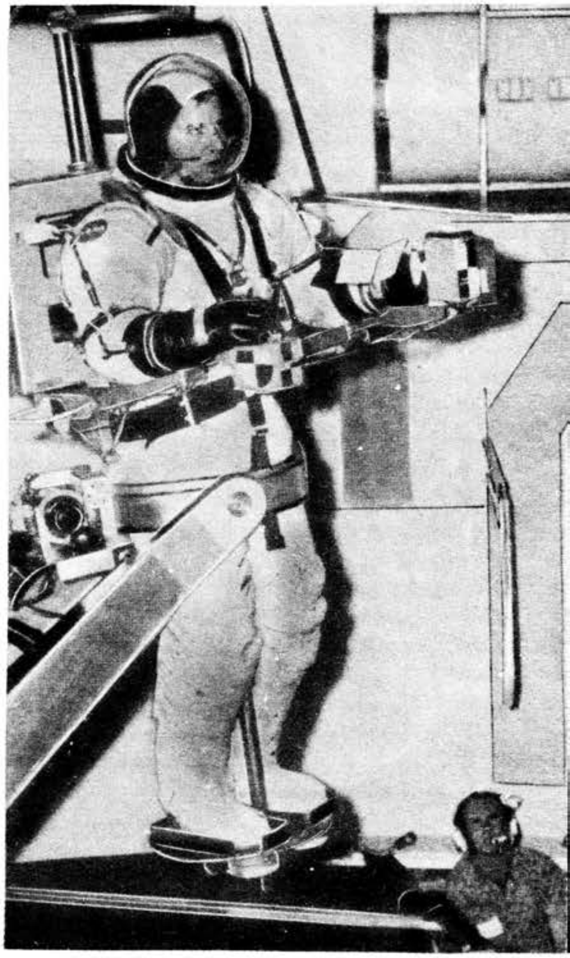
THIS IS WHY WE NEED YOUR HELP! If you have not already done so, please complete and send the new form to your Bank *A T ONCE.*

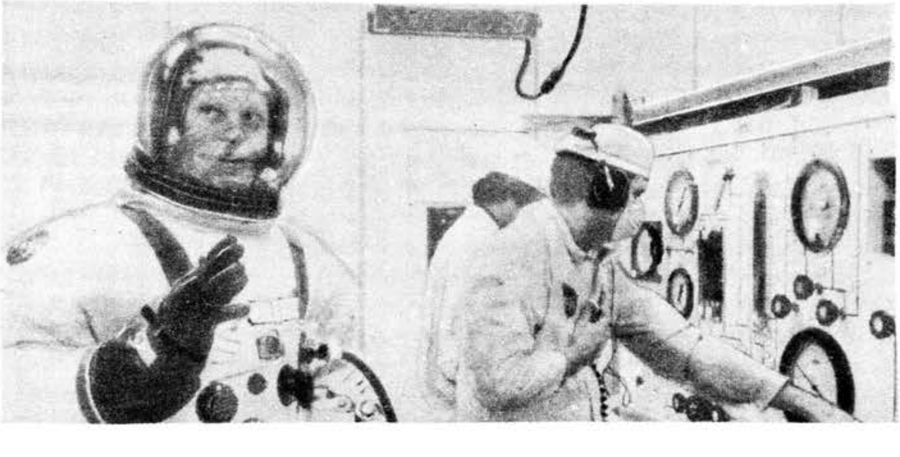
SPACEFLIGHT

88905 КОСМИЧЕСКИЕ ПОЛЕТЫ № Т-12
(спейсфлайт)
По подписке 1973 г.

Volume 15 No.12 December 1973







Published by The British Interplanetary Society

SPACEFLIGHT

A Publication of The British Interplanetary Society

VOLUME 15 NO 12 DECEMBER 1973 *Published 15 Nov. 1973*

CONTENTS

COVER

MAN-PROPULSION. During the second astronaut occupation of the Skylab space station, Capt. Alan Bean tested the Astronaut Manoeuvring Unit (AMU) backpack developed for NASA by Martin Marietta Aerospace within the Orbital Workshop flying at speeds of about 2 ft/sec. Powered by nitrogen gas jets, the AMU is meant to assist the design of future man-propulsion systems for use in free space. As long ago as June 1966, a prototype AMU was incorporated in the back of the Gemini 9 adapter module, which astronaut Gene Cernan was to test during EVA. On that occasion spacesuit overheating and difficulties in opening one of the AMU's arm rests frustrated the experiment. *Top left,* astronaut Bruce McCandless tries out the AMU in a pre-flight test at Martin Marietta. *Right,* Paul Weitz trains on the Astronaut Manoeuvring Unit Simulator. *Below,* astronaut Jack Lousma undergoes last-minute spacesuit pressure checks before being launched with Alan Bean and Dr. Owen Garriott on 28 July 1973 at the start of a record 59-day stay in space.

Martin Marietta Aerospace/ National Aeronautics and Space Administration.

MILESTONES

Sep

5 Skylab commander Capt. Alan Bean breaks Charles Conrad's world record of 49 days, 3 hours 37 minutes accumulated time spent in space.

13 NASA doctors give Skylab astronauts the go-ahead to complete their planned 59-day mission.

16 Anita, one of the two spiders aboard Skylab, is found dead. Probable cause of death (according to Dr. Garriott) was diet of filet mignon instead of live flies.

22 Skylab astronauts Bean and Garriott spacewalk to replace film canisters in Apollo Telescope Mount.

23 Kettering Grammar School Satellite Tracking Group pick up signals from their 300th satellite, Cosmos 587.

24 Memorandum of Understanding between ESRO and NASA is signed in Washington – by Dr. Alexander Hocker and Dr. James C. Fletcher – whereby ESRO agrees to design and build Spacelab for use with America's re-usable space shuttle.

25 Skylab astronauts Cpt. Alan Bean, Major Jack Lousma and Dr. Owen Garriott splash down in Pacific at 11.20 BST, after record space flight of more than 24 million miles lasting 59 days. Capsule is hoisted on to deck of helicopter carrier *USS New Orleans* with astronauts aboard. Scientific return includes 17,000 photo's of Earth, 75,000 pictures of Sun and 25 million miles of taped data.

27 Soviets launch Soyuz 12 at 3.18 p.m. (Moscow time) from Baikonur cosmodrome with cosmonauts Lt-Col. Vasily Lazarev, 45, and flight engineer Oleg Makarov, 40. Two-day programme includes: comprehensive checking and testing of improved flight systems, further testing of manual and automatic controls in various flight conditions and spectrography of separate regions of the Earth – from visible to IR – to obtain data 'for the solution of economic problems'. Initial orbit: 194-249 km inclined at 51.6 deg to equator, period 88.6 min. Cosmonauts have new design spacesuits which can be taken off in orbit and put on again for return to Earth. Communication with Soyuz mission control, while spacecraft is beyond territory of USSR, is maintained *via* Molniya 1 communications satellite and tracking ship *Akademik Sergei Korolyov* in the Atlantic.

28 Soyuz 12 manoeuvred upward to achieve 326 - 345 km altitude orbit at same inclination to equator; period 91 min.

28 Arabella, one of the two spiders placed aboard Skylab, is found dead at the Marshall Space Flight Center at Huntsville, Alabama.

29 Soyuz 12 cosmonauts soft-land some 400 km south-west of Karaganda, Kazakhstan, at 2.34 p.m. (Moscow time). A spokesman of the flight control team says that 'future space flights will become longer and be made further and further from the Earth; it was therefore important constantly to improve autonomous methods of navigation'.

Oct

1 A 47-member NASA delegation begins two weeks of meetings in Moscow on the Apollo-Soyuz Test Project (ASTP).

В журнале не печатается ряд страниц.

T 2

AMERICA'S FIRST LONG-RANGE MISSILE AND SPACE EXPLORATION PROGRAMME

By Dr. Frank J. Malina**

THE ORDCIT PROJECT OF THE JET PROPULSION LABORATORY, 1943-1946*

Although the German group at Peenemünde has been credited with making large advances in rocket technology which led to the age of space exploration, the role played by American rocket pioneers of the California Institute of Technology in the 'Forties was also extremely significant in spurring the development of propulsion systems and step-rocket techniques. In this memoir a leading member of this group gives a personal account of the researches which set the stage in America for the practical development of artificial satellites and interplanetary probes. Readers will be interested to know a few high-points in the subsequent careers of persons who played key roles in this work:

***Theodore Von Kármán* (1881-1963) left the California Institute of Technology in 1944 to establish the Science Advisory Group of the US Air Force ; in 1951 he took steps to bring into being the NATO Advisory Group for Aeronautical Research and Development (AGARD) ; in 1959 he was asked by the International Astronautical Federation to be Chairman of the Founding Committee of the International Academy of Astronautics of which he became its first President in 1960.**

***Frank J. Malina* left the Jet Propulsion Laboratory in 1946 to become a member of the secretariat of Unesco in Paris ; in 1953 he became a professional artist ; in 1959 he was a member of the Founding Committee of the International Academy of Astronautics and is now a Trustee - Past President; in 1968 he launched the international journal of the art and science, *Leonardo*, of which he is the Editor.**

***Hsueh - Shen Tsien* (now Chien Hsueh - sen) became Goddard Professor of Jet Propulsion at the California Institute of Technology in 1948. He returned to China in 1955 and is a member of the Academy of Sciences of the Peoples Republic of China. Reports suggest that he has played a leading role in developing China's long-range rockets.**

***Martin Summerfield* is a Professor in the Department of Aerospace and Mechanical Engineering Sciences at Princeton University ; editor of *Astronautica Acta* and of a series of books on *Progress in Astronautics and Aeronautics*.**

***Homer J. Stewart* is Professor of Aeronautics at the California Institute of Technology and Special Assistant to the Director of the Jet Propulsion Laboratory, NASA.**

***Louis G. Dunn* became Director of the Jet Propulsion Laboratory in 1947. He left JPL in 1954 for Space Technology Laboratories, Ramo — Wooldridge Corporation, of which he became President.**

***William H. Pickering* is Professor of Electrical Engineering at the California Institute of Technology and Director of the Jet Propulsion Laboratory, NASA, at Caltech.**

Kenneth W. Gatland

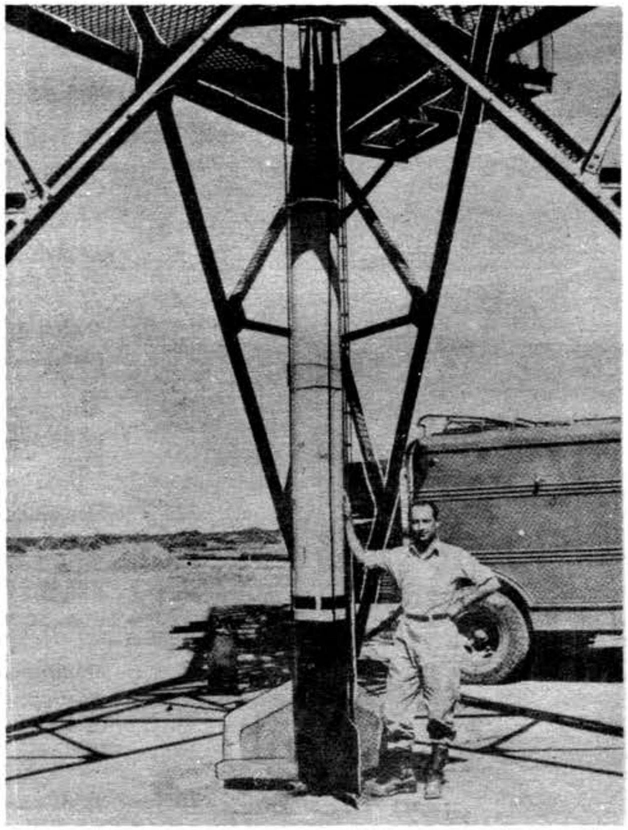


Fig. 1. The author beside the WAC CORPORAL, the world's first successful sounding rocket, White Sands Proving Ground, New Mexico, U.S.A., October 1945.

Introduction

The years covered by this memoir were extremely hectic compared to those discussed in my first two memoirs [1,2] (Fig. 1). It is very difficult for me even now to draw anything like a clear and coherent picture of them. Nevertheless, I hope that what I have to say will be of use to historians of astronautics by drawing attention to unpublished material available in the archives of the Jet Propulsion Laboratory. The Biweekly Research Conference Minutes especially give a vivid account of the evolution of the developments I shall discuss.

Between 1943 and 1947 I became more and more an administrator of research. The Air Corps Jet Propulsion Research Project, GALCIT (The acronym stands for Guggenheim Aeronautical Laboratory, California Institute of Technology) [2], which numbered around 85 persons in 1943 grew by 1946 to about 400 and the amount of money to worry about increased from hundreds of thousands to millions of dollars annually. Whereas I was directly acquainted with all that was taking place on the Project up to 1944, both as regards ideas and their execution, by 1946 I was aware of more and more research activities but in less and less detail, and little of my time was free for carrying out research of my own — a situation not pleasing to one of my temperament.

Theodore von Kármán's (Fig. 2) connection with the California Institute of Technology (Caltech) became increasingly tenuous in 1942 and in 1944 he became absorbed by activities centered in Washington, D.C. [3], where he took up residence. As a result, in 1944 I had to take over contract negotiations from both technical and management points of view, which required frequent trips to Wright Field at Dayton, Ohio, to Washington, D.C. and to other places. Life became a 'between trips' kind of existence.

By 1944 it was fairly evident that World War II would end

* *Abridged version of a paper prepared for the 5th International Symposium on the History of Astronautics organised by the International Academy of Astronautics at Brussels, Belgium, on 23 September 1971.*

** *17 Rue Emile Dunois, 92100 - Boulogne-sur-Seine, France.*

in the defeat of the evil forces of fascism in Germany, Italy and Japan. But what then? The harnessing of atomic energy for destructive purposes was demonstrated at Alamogordo, New Mexico and then at Hiroshima and Nagasaki, Japan, in 1945. As I was drawn into the councils of those with military responsibilities, I participated more and more in discussions of what should be done in the next war with long-range rocket missiles. Obviously, if atom bombs could be made light enough, they would be used as warheads on missiles. Such deliberations became more and more distasteful to me as the months went by. Since I had long been convinced that war between or by advanced technology nations was a form of national insanity, even before a way to release nuclear energy had been found, it seemed to me that ideas and effort were really needed now to find ways for 'sovereign' nations to function in peace together rather than to develop better means of destroying themselves.

I was mentally and physically exhausted by 1946. General Eisenhower is said to have remarked when the war ended that all he wanted to do was to go fishing; I felt the same way, except that I do not care much for fishing. I had had ten years of experience with research involving rocket problems on the fringes of basic and engineering science knowledge; of devices requiring the use of explosives and toxic chemicals; of concern for the safety of our staff and of aircraft test pilots; of frustrations resulting from dealings with administrators who had no grasp of the nature of research, and of travel by train and by air to meetings that frequently were not really necessary. This experience forced me, at the age of 34, to make a serious appraisal of myself and of my hopes for the future.

When we had begun rocket research at Caltech in 1936, most of our original group of 6 was dedicated to the peaceful uses of rocket propulsion [1]. The design of a sounding rocket was our first goal. But world developments by 1938 dictated our participation in the military application of rocket propulsion, though I never lost sight of our first goal. When in 1945 the WAC Corporal became the first successful sounding rocket to exceed heights attainable by any other means, I felt a sense of personal fulfillment. I understood that this was but the first probe into extraterrestrial space and that voyages to the Moon and planets would follow but I also knew that there were now many others who would carry on the work necessary to reach these more distant goals. In 1936, the number of engineers in the world seriously interested in astronautics was probably less than 50; by 1946 there were several hundreds.

Fig. 2. Theodore von Kármán at a party for his 60th birthday, Pasadena, California, U.S.A., 3 May 1941.

What troubled me most in parting from JPL was the separation from the members of the staff, many of whom were my closest friends and with whom I had shared many good and many trying times. I have never again worked with a group that was as cooperative and enthusiastic.

My new goal became international cooperation. Although I left Caltech with a two-year leave of absence, which was renewed in 1949, I then allowed it to lapse and, in one way or another, I have devoted myself to this goal during the past 25 years. The night before I departed from Texas for Unesco in Paris, a last effort was made to dissuade me from leaving the Jet Propulsion Laboratory. A general officer of the Ordnance Department telephoned me from Washington, D.C. and urged me to reconsider my decision. When I had asked von Kármán for his advice, he told me that if he were younger he would follow a similar path to the one I was considering; therefore, it was unlikely that anyone else would get me to change my mind.

I made a tour of the East Coast to discuss Unesco with many persons before going to Paris. Albert Einstein thought that major points of the Unesco programme were worthwhile. He said we must have courage to fight for real issues and not allow Unesco to become impotent like the Commission for International Intellectual Cooperation of the League of Nations. Vannevar Bush said scientists must get together to work on stopping wars for good. He did not know very much about Unesco but was all for it. Lyndon B. Johnson, who was then Congressman from the district of my home in Texas, said he was not acquainted with Unesco intentions and that the United Nations was just a baby.

Upon my arrival in Paris, the first task I was given by Joseph Needham, Head of the Natural Science Section of Unesco, was to study ways of breaking down the barriers to the free movement of scientists and engineers between nations! It certainly was not true that I became a member of the Unesco secretariat as a rocket expert, as was stated in an article hostile to the organisation in the *Saturday Evening Post* entitled 'Julian Huxley's Zoo'. Unesco did not come within a smell of rockets before the International Geophysical Year (IGY) in 1957.

Nevertheless, my interest in astronautics continued and while at Unesco, outside my official duties, I wrote in 1950 a popular article entitled 'Unmanned Rockets towards Space' upon the invitation of Kenneth W. Gatland, who was to be the editor of a collection of articles for a book called 'Rockets into Space'. The venture was given up by the publisher in 1954.

In that year, I also wrote 'A Short History of Rocket Propulsion up to 1945' for the Princeton University series of volumes on Jet Propulsion and High Speed Aerodynamics of which at that time Martin Summerfield was General Editor. The article was finally published in the volume 'Jet Propulsion Engines' in 1959 [4].

I terminated my Unesco appointment in February 1953 to pursue, as a painter, my long-held fascination with the relationships between art, science and technology. I did not re-

enter astronautics until after the launching of the Sputnik by the Soviet Union in 1957, which made more evident than ever the need for international cooperation in this field. Andrew G. Haley, one of the founders with us of the Aerojet General Corporation [2] and then President of the International Astronautical Federation, and von Kármán, who had become active in Federation affairs, told me that it was all very well for me to work quietly as an artist in a Paris studio but that my experience with astronautics and with the problems of international cooperation was wasted. They urged me to participate in the work of the Federation [3]. After much debate, my wife and I decided I would accept an appointment as representative of the Federation to Unesco. By 1959, I was again devoting most of my time to astronautics in the Federation, especially in connection with the establishment and direction of the International Academy of Astronautics.

But to return to the main subject of this memoir....

The Situation in 1943

The Air Corps Project at the beginning of 1943 was consolidating the successful development of solid and storable liquid propellent engines for aircraft superperformance applications, with research directed to improving the propellents and to trying new ones, to raising engine performance and to increasing their thrust and duration. Cooperation on matters of development and production was maintained with the Aerojet Engineering Corporation for those programmes sponsored by the US Air Corps and the Navy [2].

The Project had placed solid and storable liquid propellent rocket engine design on a sound scientific foundation. Practical information had been provided to engineers to permit the design of uncooled motors to meet desired specifications for thrusts up to around 2 tons for durations of up to around 75 seconds. By the end of World War II, information was available on the design of cooled liquid propellent engines and pump design was well advanced.

Albert A. Christman in his history of the Naval Weapons Center, China Lake, California, 'Sailors, Scientists and Rockets', writes: 'A suggestion by a Navy captain that it would be desirable to have a cooperative effort between Goddard and Malina brought out Goddard's view that the work in Pasadena was about the stage in 1940 that his had been in 1925. He referred to the Caltech programme as the 'Student Work' [5]. Goddard evidently did not subscribe to von Kármán's outlook: 'It is always wise to remember that someone else might be just as clever as oneself'.

Goddard's opinion of our efforts does not surprise me [1] but he must have been surprised when within two years after he made his remarks we had successfully developed and put into production for the Air Forces and the Navy service-type solid and storable liquid propellent engines. These became, respectively, the progenitors of the engines in, for example, the Sergeant, Polaris, Minuteman and Titan missiles and the Apollo Command Module and Apollo Lunar Excursion Module.

This raises an interesting question as regards what happened in Britain, U.S.A. and U.S.S.R. after the end of the war that should be probed by historians of rocketry and astronautics. I believe a good case can be made to show that the obsession of the military services in these countries for continuation of certain developments of German rocket technology caused a vast waste of funds by giving priority to rocket engines using liquid oxygen (LOX), as in the case of the V-2. In America, though the development of engines using a composite solid propellent and a storable liquid propellent combination was not dropped, it was certainly given a lower priority. Today, not a single American military operational missile uses a LOX engine; instead they are propelled by descendants of solid and liquid propellent engines developed at JPL before the end of World War II.

Fig. 3. Hsueh-Shen Tsien (Chien Hsueh-sen) on the occasion of receiving his Ph.D. (Aeronautics) degree at the California Institute of Technology, Pasadena, California, U.S.A., June 1939.

The investment in LOX engines turned out to be an overall technological gain, for they were needed for extraterrestrial space activities but these were not then and are not now of primary interest to the military services in America. What is more, solid and storable liquid propellents also have an important role to play in the propulsion of spacecraft at this phase of the 'space age'.

Popular opinion, even the opinion of some who should know better, has been that American rocket developments lagged far behind that of Nazi Germany. This belief is false but myths die hard.

Origins of the ORDCIT Project

At the Air Corps Project in 1943 we were following directives of 1939 that limited us to rocket engines to be used in connection with aircraft [2]. This situation was radically transformed in the summer of 1943.

Von Kármán received in early July 1943 a request from the Commanding General of the AAF Materiel Center, Wright Field, to study and comment on three British intellegence reports on reaction propulsion devices for projectiles and aircraft supposedly being developed in Germany [6, 7, 8.]. Comments on the reports, based on an investigation that he, Hseueh-Shen Tsien (Chien Hsueh-sen) (Fig. 3) and I made, were sent by him to Wright Field on 2 August. Although much of the data from German prisoners in the reports was wrong, inexact and exaggerated, it was possible to arrive at some interesting conclusions. The fact that the conclusions bore little resemblance to actual German missile and aircraft developments, as was learned later, is irrelevant to their impact on the American military scene in 1943. Fascinating background material on these intelligence reports, to be read with circumspection, can be found in the book *The Mare's Nest* by David Irving [9].

The AAF Liaison Officer at Caltech at this time was Col. W. H. Joiner, a most congenial and cooperative officer. He immediately appreciated the significance of our comments on the reports and suggested to me that a study should be made of the possibility of propelling missiles using the rocket engines we had developed or that were available at Aerojet. I turned to Tsien for help and the two of us completed our study in November 1943 [10]. Our results showed that although ranges in excess of 100 miles could not be reached with engines then available, rocket missiles could be constructed that had a greater range and a much larger explosive load than rocket projectiles then being used by the Armed Forces. Von Kàrmàn, after discussing the analysis with us, decided to attach a memorandum to our report proposing that a development programme be initiated along the lines we had indicated [11].

These documents for the first time carried the name 'Jet Propulsion Laboratory' [2]. The memorandum and analysis were sent by Joiner to the Commanding General at the AAF Materiel Center. In an adjoining office at Caltech was Captain R. B. Staver, who was liaison Officer at Caltech for the Ordnance Department. Staver forwarded the same documents to Colonel G. W. Trichel, Chief of Rocket Development Branch of the Ordnance Department [2].

Von Kármán, Tsien and I at this point concentrated our thoughts on the technical problems of long-range missiles and on what appeared to us to be the most reasonable steps to be taken to develop them on the basis of current American experience with solid and liquid propellent rocket engines. Staver has recently drawn my attention to quite a different thought process that occupied his and Joiner's minds. They were concerned with assuring continued support of the development of rocket and other types of jet engines and of their application by the military services after World War II, fearing the historic tendency of American governments to drop potentially important research for military purposes when a war ended. Furthermore, they felt that our Project should not only be continued but expanded to become the centre of jet propulsion and of missile research and development [13].

The response of the military services to the above two documents on the devlopment of long-range missiles planted one of the seeds for the bitter inter-service military rivalry that took place in America in the 1950's. I recall discussions with officers in the Air Force and in the Ordnance Department on the appropriate 'botanical' classification of a rocket missile. Those concerned with army ordnance said that, since long-range guided missiles followed a ballistic trajectory like a gun projectile, such missiles were clearly a responsibility of the Ordnance Department. Those responsible for long-range bomber aircraft said that, since a long-range guided missile needed aerodynamic control during the first phase of flight in the atmosphere, it was the Air Forces that should be responsible for their development and they called the missiles 'pilotless aircraft'.

The AAF did not respond to our proposals, much to our amazement. Instead, von Kármán received a letter dated 15 January 1944 from Trichel of Army Ordnance expressing not only interest in the proposed programme but a desire that Caltech undertake a more intensive programme than was outlined [12].

Trichel urged that a revised and more inclusive programme be commenced at the earliest possible date. He further stipulated that the Ordnance Department was prepared to furnish the necessary funds to cover such a project, providing the Institute, in turn, was willing to give the necessary emphasis to the undertaking in the assignment of personnel and facilities. Also recommended was that a proposal be submitted that would include a chronological schedule of the studies to be made, models built, etc., further, if such a project was decided upon, it would be advisable to make a contract with Caltech on a cost-plus-a-fixed-fee basis. The plan of operations should initially cover not more than one year and the expenditures should not be more than $3,000,000 for the one-year programme.

The scale of operations envisaged threw us into a proper dither! We prepared a new proposal incorporating Trichel's suggestions, and von Kármán, with the support of Robert A. Millikan, Chairman of Caltech's Executive Council (father of Clark B. Millikan), obtained the approval of the Caltech Trustees to put forward the proposal to the Ordnance Department.

On 28 February, von Kármán submitted on behalf of Caltech the new proposal, based on Trichel's suggestions, to Major General G. M. Barnes, Chief of the Technical Division, Ordnance Department, in Washington, D.C. This proposal was accepted practically intact [12].

A Letter of Intent for the Army Ordnance programme was placed with Caltech on 22 June 1944: 'for services consisting of research, investigation and engineering in connection with the development of a long-range rocket missile and launching equipment and for complete reports, drawings and specifications describing all work done in connection therewith'. An expenditure not exceeding $1.600,000 was authorised. This was followed by a definitive contract, which entered into force on 16 January 1945, with the following objectives [12]:

a) Missile was to have a minimum weight of highly explosive payload of 1000 lb.

b) Maximum weight of missile was not to exceed weight consistent with good design and maximum payload.

c) Range of missile up to 150 miles.

d) Dispersion at maximum range not in excess of 2% on a missile suitable for direction by remote control.

e) Velocity sufficient to afford protection from fighter aircraft.

The termination date of this contract was 22 December 1945; however, it was amended to extend through 30 June 1946; the total funds provided amounted to $3,600,000.

This expanded programme led to a re-organisation of the Air Corps Jet Propulsion Research Project, GALCIT into the Jet Propulsion Laboratory, GALCIT. The programme was given the designation ORDCIT Project (ORDCIT is an acronym for Ordnance-California Institute of Technology).

Reorganisation of the Air Corps Project into the Jet Propulsion Laboratory, GALCIT

The ORDCIT Project required a rapid expansion of the staff and facilities of what I shall from now on refer to as the Jet Propulsion Laboratory (GALCIT) or,for short,JPL. During the period under consideration, JPL was attached to the Guggenheim Aeronautical Laboratory (GALCIT) of which von Kármán was director. He remained titular director until 1949 when he became Professor Emeritus and Clark B. Millikan became his successor. By this time, JPL had been separated from GALCIT and came directly under the overall administation of Caltech.

While we were in the midst of preparing plans for carrying out the programme of the ORDCIT Project, von Kármán underwent serious abdominal surgery at the end of May, 1944, in New York City, which prevented his return to Pasadena until September. It was while he was recuperating in New York that General H. H. Arnold, Commanding General of the AAF, approached him to undertake the creation of the Scientific Advisory Board to the Chief of Staff of the AAF 'to investigate all possibilities and desirabilities for postwar and future war's development as respects the AAF'. Von Kármán left for Washington, D.C.,in December, not to return to Caltech except for short periods of time.

The scope of the ORDCIT Project posed to the administrators of Caltech novel problems as regards the range of activities, the size of staff and the amount of money involved. It was decided to establish a JPL Executive Board, responsible to the Caltech administration, whose task would be to oversee the general policies of JPL administration and to take cognizance of the implications of any new technical developments that took place. When von Kármán took leave of Caltech, the question of who would be responsible for directing JPL had to be resolved. C. B. Millikan was asked to become Chairman of the JPL Executive Board and I took over direction of JPL [16].

In 1944, Col. L. A. Skinner was designated Liaison Officer for the Ordnance Department. Those of us concerned with solid propellent rocket engines were acquainted with his studies in the 1930's of nitroglycerine-nitrocellulose as a propellent. I also had met him when he was working with the 'Indian Head Group' at Indian Head, Maryland, in the early 1940's [5]. Joiner was suceeded by Col. E. H. Eddy as Liaison Officer for the AAF and Lt. Col. J. W. Newman was designated Liaison Officer by the Army Ground Forces.

Research at JPL was carried out, beginning in 1944, on four major projects: JPL-1 (Project MX 121 of the Aircraft Laboratory of the AAF Materiel Command, was a continuation of aspects of the programme previously carried out for the Aircraft Laboratory) [2]; JPL-2 (Project MX 363 of the Armament Laboratory of the AAF Materiel Command, begun in 1943 [2], was on hydrobomb research); JPL-3 (Project MX 527 of the Power Plant Laboratory of the AAF Materiel Command, begun in 1944, was primarily on ramjet engine research)[2] and JPL-4 (The ORDCIT Project).

The ORDCIT Project involved not only fundamental engineering research on thermal jet propulsion engines, propellents and the design of guided missiles but also the construction of missiles and of launching devices for firing tests. The firing tests were to be made in cooperation with the Ordnance Department. This required us to become accustomed to thinking in terms of design and construction of a very different kind and on a much larger scale than before. We were greatly helped in confronting this situation by Romeo R. Martel, Professor of Civil Engineering at Caltech and member of the JPL Executive Board, and by Aladar Hollander of the Byron Jackson Company of Los Angeles, a manufacturer of pumps. The design of large constructions required for the development and launching of missiles was guided by William A. Sandberg of the Consolidated Steel Company of Los Angeles. Mark Serrurier of Caltech supervised the design of installations for ramjet engine studies. E. M. Pierce, Sr., an architect who had been my personal assistant since 1943, and W. Hertenstein, head of maintenance and buildings at Caltech, bore the brunt of designing and contracting for new buildings to be constructed as quickly as possible. The construction programme was aided in every way by the Ordnance Liaison Officers – by Skinner up to August 1945 and thereafter, by Colonel Benjamin S. Mesick, V. C. Larsen, Jr., who in 1946 took charge of Laboratory administration was in charge of materiel procurement. William R. Stott, Assistant Comptroller at Caltech,and I spent many days on contract negotiation.

The chiefs of Technical Sections were the following: H. J. Stewart, Section 1, Research Analysis; J. V. Charyk, Section 2, Underwater Propulsion; H. S. Seifert, Section 3, Liquid Propellent Rocket Engines; C. Bartley, Section 4, Solid Propellent Rocket Engines; P. Duwez, Section 5, Materials; S. A. Johnson, Section 6, Propellents; W. B. Barry, Section 7, Engineering Design; J. Ammeus, Section 8, Research Design; W. H. Pickering, Section 9, Remote Control W. D. Rannie, Section 10, Ramjet Engines; and S. J. Goldberg, Section 11, Field Testing.

Tsien, who had been the first chief of the Research Analysis Section, left Caltech for the Massachusetts Institute of Technology in 1946. He returned in 1948 to set up the Jet Propulsion Center established at Caltech by the Daniel and Florence Guggenheim Foundation. Martin Summerfield returned to JPL from the Aerojet Engineering Corporation in the autumn 1945 to take part in planning and research analysis of possible applications of rocket propulsion to extraterrestrial space flight.

My 1944 Mission to Europe

JPL was visited in the summer of 1944 by Colonel F. F. Reed, called by his friends 'Froggy'. He was Assistant Military Attache, Ordnance Department, in London. It was decided that I should return his visit by going to Britian to study rocket and ramjet engine research underway, to obtain first-hand experience of being in the target area of the V-1's and V-2's, and to inspect at Farnborough, England, the parts of the V-2 that had been obtained from the one that had strayed off course and landed in Sweden in early 1944.

Since my trip included an inspection of German V-1 launching sites and other kinds of installations in northern France (Pas de Calais region), which had been liberated in August 1944, I was given the rank of Colonel (assimilated rank, in case of capture). Upon the urging of Reed, I designed and had

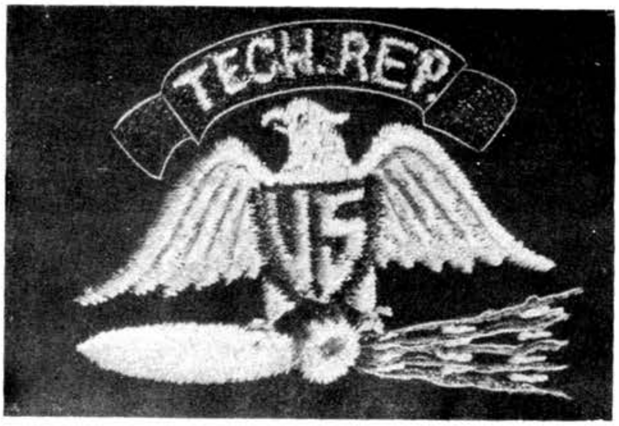


Fig. 4. Unofficial U.S. Army uniform shoulder patch worn by author in the European Theatre of Operations, November 1944.

a tailor make a shoulder patch with a rocket on it – perhaps the first US military insignia signifying rocket missiles (Fig. 4).

There are 82 names of engineers and scientists in the UK on the list of those with whom I discussed various aspects of my mission. Among these were Sir Alwyn D. Crow, Controller of Projectile Development, London; W. Blackman, Chief Superintendent, Projectile Development Center, Aberporth, Wales; J. E. Lennard-Jones, Chief Superintendent, Armament Research Department, Fort Halstead; R. F. Fraser, Imperial College of Science and Technology, London; S. Goldstein, Cambridge University; Thomas, Petroleum Warfare Department, Langhurst; Hankins and Ralph, respectively Superintendent of the Engineering Division and Superintendent of the Aerodynamics Division of the National Physical Laboratory, Teddington; Perring, Royal Aeronautical Establishment, Farnborough; Capt. A. Richards, Superintendent of Torpedo Exp. and Dev., Greenoch, Scotland; I. Lubbock, Asiatic Petroleum Co.; B. Lockspeiser, Director of Scientific Research, Ministry of Aircraft Production; Air Commodore F. Whittle, Power Jets,Ltd., Whetstone; Smith, Metropolitan-Vickers,Ltd., Manchester.

These discussions were quite open on both sides, although I knew that some information was held back, just as I held back on some of our plans and developments. Compared to American research practice, the extent of theoretical analysis and the length of debate on pros and cons before a decision was made to build something particularly struck me. This difference in approach was in large part due to the much more limited financial and manpower resources available in wartime Britain. I realise that our PRIVATE F fiasco (to be described later) might well have been avoided if a more thorough theoretical analysis had been made of an unguided winged missile.

The main interest in Britain in 1944 was centered on the improvement, under the dominating personality of Sir Alwyn Crow, of an anti-aircraft rocket missile. Under his leadership, unguided anti-aircraft ballistite UP rockets (UP for Unrotated Projectile) were developed and used in the Battle of Britain in 1941. Some said that the UP's should have been called 'misguided' missiles, for, as Charles C. Lauritson, who watched them perform in London that year is quoted to have said: 'I don't think they ever shot down a bomber;...' ([5] p. 108). They did make a lot of noise, which perhaps gave a psychological lift to the people.

By the time I arrived in London in October 1944, only a few V-1's were still arriving during the night, launched from aircraft over the North Sea because land launching sites on the other side of the English Channel had been captured by the Allies. V-2's bombarded London from bases off the coast of Holland. One shook up a conference I was attending at Fort Halstead, near London. My first experience of this sort left me rather disturbed but not my colleagues, who continued the meeting as though nothing had happened.

Information was available on the V-2 and on German engines using LOX and hydrogen peroxide (H_2O_2). The British were of the view that the nitric acid-aniline family of propellents was less suitable than hydrogen peroxide and, hopefully, nitromethane. We did not go overboard on either of these latter chemicals as they did. (By 1944, we had good reasons to doubt the great expectations of John W. Parsons and Fritz Zwicky for nitromethane as a monopropellent. It was tested extensively both at JPL and at Aerojet and, as far as I know, nitromethane was finally given up as a rocket propellent because it is sensitive to shock and it is difficult to use as a rocket motor coolant). Test facilities for liquid propellent engines were still in a very primitive state in Britain and work was just getting underway on composite solid propellents and on long duration engines using them.

There was much interest in the possibilities of the ramjet engine, mainly because of claims made for it in Germany, especially by Eugen Sänger. The British knew considerably more than we did at JPL of the problems to be solved to make a ramjet a practical device [2]. Ramjet studies were being carried out in England at Power Jets, Ltd., under Lloyd and Constant. Here, also, Air Commodore Frank Whittle was continuing his development of turbojet engines and he and I compared experiences on the vicissitudes of those who try to get unorthodox ideas accepted.

I inspected the parts of the V-2 brought from Sweden at the Royal Aircraft Establishment at Farnborough. Design elements of the engine and the guidance system were then still not completely understood. The latter was especially of interest to us at JPL where we were just beginning to confront the problems of missile guidance and control.

Between 16 and 26 November 1944 I visited France with Captain C. E. Martinson, who had been assigned by Reed to look after me during my mission. We inspected V-1 launching sites at Wizerne, Montreuil and Siracourt. Bombing from aircraft had produced only minor damage to the sites, whereas nearby villages were in shambles. At Mimoyecques and Watten were very large constructions whose purpose up to that time no experts could make out.

While crossing the Atlantic on my return journey during the second week of December, the many hours gave me a chance to think over the implications of all I had observed on my tour. When I had departed from JPL in October, plans were far advanced for testing the first ORDCIT solid propellent missile, the PRIVATE A, for the design of a winged version, the PRIVATE F, and for the liquid propellent CORPORAL. Turning over the many bits of information stored in my mind, I clearly realised that the first objective our rocket research group had set for itself in 1936 was within reach – a sounding rocket [17 - 19]. We now had reliable solid and liquid propellent engines around which to build it.

The next step was to sell the idea to the Ordnance Department.

I visited Trichel and his staff during a stop-over in Washington, D. C., to report on my mission, before proceeding on to Pasadena. When I completed my report, I presented my wish to have JPL design, construct and test a sounding rocket. I explained that it should be possible to carry out the programme rapidly; that modest requirements should be set (to lift a 25 lb. payload to 100,000 ft.); that the rocket with a liquid-propellent engine could be considered as a small-scale test version of the CORPORAL; that experience would be gained with launching techniques and that it might be considered a first step in the development of a guided anti-aircraft missile. The proposal immediately raised a favourable response. The Signal Corps was contacted to establish meteorological payload requirements for the rocket that would meet its needs [2]. By 16 January 1945, the study of the proposed sounding rocket requested from JPL by the Ordnance Department was completed by Homer J. Stewart and me [20].

Fig. 5. PRIVATE A solid propellent missile in flight at Camp Irwin, California, in the Mojave Desert, December 1944.

PRIVATE A

The first missile to be tested used a solid propellent rocket engine that could be quickly provided, as proposed by Tsien and me in 1943 [10]. It was called PRIVATE A, with the intention to name subsequent missiles in hierarchical order of army ranks. The JPL missile series ended in 1954 with the SERGEANT, a solid propellent surface-to-surface missile with an inertial guidance system.

The PRIVATE A (also designated XF 10S1000-A) was designed to provide experimental data on the effect of sustained rocket thrust on a missile stabilised with fixed fins and on the use of booster rockets for missile launching [21]. It had a length of 92 in., a maximum diameter of 10¼ in. and 4 tail fins extending 12 in. from the body. The gross weight was 500-550 lb., including a payload of 60 lb. The solid propellent motor, manufactured by the Aerojet Engineering Corp. (now Aerojet General Corp.) delivered a thrust of 1,000 lb. for about 30 sec. The specific impulse of the GALCIT 61C asphalt-base castable propellent was 186 sec.

The launcher was a 36 ft. long rectangular steel boom of the truss type, with four guide rails inside the truss. It was mounted on a steel base and both the lateral and vertical angles could be varied.

The missile was boosted by 4 modified Ordnance Department aircraft armament rockets in a cluster, which delivered a total thrust of 22,000 lb. for 0.18 sec. They completed their burning and disconnected from the missile before it left the launcher. Full details on the design of the PRIVATE A, its booster and launcher can be found in Refs. 22 - 24.

Firing tests were made in the Mojave Desert at Leach Spring, Camp Irwin, near Barstow, California, between 1-16 December 1944 while I was in England. Twenty-four rounds were fired, with an average range of approximately 18,000 yd. the maximum range was 20,000 yd. or 11.3 miles. The missile reached an estimated peak height of 14,500 ft. and an estimated maximum speed of 1,300 ft/sec. A view of the smoke trail of a PRIVATE A in flight is shown in Fig. 5. Trajectory analyses were carried out by W. Z. Chien and C. C. Lin [25, 26]. The firing tests were completely successful, meeting all of the objectives specified for the programme. The PRIVATE A became the direct precursor of American composite propellent rocket engine missiles, the SERGEANT, POLARIS, MINUTEMAN, and POSEIDON and of anti-missile missiles.

PRIVATE F

Tsien and I in the memorandum of 1943 [10] also proposed the addition of wings to a missile having the characteristics of the PRIVATE A, estimating that the range would be increased by around 50% but with a reduced payload. We pointed out that the problems of stability and control of such an unguided missile were very complicated.

The winged PRIVATE A was designated PRIVATE F (also XF 10S1000-B) [21]. The same Aerojet solid propellent engine was used. The missile was provided with fixed wings having a span of 5 ft., stubby wings of 3 ft. span at the forward end for trimming the aerodynamic forces and, at the rear, horizontal stabilisers and a vertical fin. The same PRIVATE A booster cluster was used. A new launcher was constructed with two rails, in order to clear the wings and tail surfaces. Design details can be found in Ref. 27.

Firing tests were made at Hueco Range, Fort Bliss, Texas, between 1-13 April 1945. The tests began on April Fool's Day and turned out to be quite appropriate to the day. All of the PRIVATE F rounds were successfully launched but each one, after a short flight, went into a tailspin. A striking corkscrew smoke trail was drawn in the sky by the rocket jet! It was concluded after a post mortem of the tests that better performance might have been obtained if the missile had been constructed with greater precision and if the lifting surfaces had been more readily adjustable [28,29].

In calmer times, when the use of funds is more carefully scrutinised, programmes, such as the PRIVATE F, would have been undertaken only after more theoretical studies of such a complex device had been made and more care would have been taken in its construction.

While tests of the PRIVATE F were underway at Fort Bliss, Texas, we visited the nearby missile test range being newly prepared for the Ordnance Department at White Sands,

New Mexico. Here facilities were being constructed for the tests of the WAC CORPORAL, which the following September inaugurated the White Sands Proving Ground, then under the command of Col. H. R. Turner.

WAC CORPORAL

The first long-range missile proposed by Tsien and me in 1943 [10] was to be boosted and then propelled by a storable liquid propellent rocket engine of the type already developed at JPL. Our proposal contained the basic design ideas that were used in the WAC CORPORAL sounding rocket, although we did not contemplate the design of a sounding rocket at the time we made the original analysis. One immediate result of our proposed third missile was the initiation in 1944 of the design and construction of a guided long-range missile called the CORPORAL, which I shall discuss later.

Since in 1943 there was not available a guidance and control system for ground-to-ground missiles, we proposed that a liquid propellent missile be boosted by an unrestricted burning solid propellent rocket out of a launcher. If launched at sufficient speed, the tail fins would provide the necessary restoring force when the missile was disturbed into yaw by a cross-wind.

The possibility of employing rocket propulsion for lifting a vehicle to great heights was realised at the beginning of this century [30]. In America, Robert H. Goddard first gave serious consideration to this possibility in about 1914. At first he studied the feasibility of using constant-volume process, short-duration smokeless powder rocket engines [31, 32]. A more rigorous analysis than Goddard's [32] of the flight performance of a rocket propelled by successive impulses was made by Tsien and me in 1939 [19]. A historical summary of sounding rockets is contained in a book recently released by NASA [33], which in my opinion, should be used with caution by historians, as there are a number of errors in those parts which relate to the history with which I am familiar.

Black powder rockets were capable of reaching several thousand feet before the 20th century and balloons in the 1930's could reach altitudes of about 100,000 ft. A successful sounding rocket, therefore, was considered to be one that surpassed the altitudes achieved by balloons. Furthermore, it should be designed to minimize costs of production and of servicing and maintenance.

Goddard in the 1920's had decided that a liquid propellent rocket engine offered better possibilities for constructing such a sounding rocket and he obtained very limited financial support for developing one from the Smithsonian Institution [34]. The Daniel Guggenheim Fund for the Promotion of Aeronautics, upon the urging of Charles A. Lindbergh, began to support this work in the 1930's at the station Goddard established near Roswell, New Mexico [34]. In 1936, Goddard published a very general report on the progress of his work at Roswell [35]. Our group at Caltech in 1936 arrived at the conclusion that the reason Goddard had not succeeded in constructing a successful sounding rocket was because he had underestimated the difficulties involved; there were too many problems for an isolated inventor to solve [1]. Even so, success for anyone in the 1920's and 1930's was not likely because rocket technology was not sufficiently advanced; there were no high-thrust, short-duration booster rocket engines and no suitable guidance systems. Goddard's LOX-gasoline rocket engines, moreover, did not provide a high enough specific impulse for the task.

Similar difficulties confronted experimenters in Germany and in the Soviet Union where a group headed by M. K. Tikhonravov first launched a liquid propellent rocket called 'Rocket 09' in vertical flight on 17 August 1933 [36]. In Germany, the V-2 (A-4) was launched in the early 1940's in vertical flight. Although designed as a ground-to-ground missile, it was used as a sounding rocket for a period in the USA beginning in April 1946 [33].

The situation in 1944 was radically different from the one that faced Goddard 10 years earlier. Solid propellent rocket engines for boosters could be taken from armament rockets being used in the war to circumvent the necessity of a guidance system within a sounding rocket. Both solid and storable liquid propellent rocket engines with a thrust of sufficient magnitude and duration, and with adequate specific impulse had been developed at JPL.

We considered the advantages of using various types of rocket engines to propel the WAC, in particular: (a) a high-thrust, short-duration ballistite engine used in armament rockets; (b) a long-duration asphalt-base GALCIT 61-C solid propellent engine of the type used in the PRIVATE A and PRIVATE F; and (c) a nitric acid-aniline liquid propellent engine with a cooled motor and a gas-pressure propellent supply system. Armament rocket engines were ruled out because the use of a single one as the main engine would have produced excessive acceleration of the WAC, which was not desirable from the point of view of mechanical design and of the high drag resulting from high flight speeds in the dense lower levels of the atmosphere.

The second alternative, the GALCIT 61-C solid propellent engine, was dropped because its weight as then designed, was excessive. For the WAC to reach an altitude in excess of 100,000 ft., it was estimated that an overall impulse-weight ratio of at least 95 sec. was necessary and not more than around 77 sec. could be obtained with the available GALCIT 61-C engine.

It was decided that the most feasible engine to meet WAC objectives would be the nitric acid-aniline engine of the type mentioned above. The motor to be used was a modified version of one designed by Aerojet to deliver 1,500 lb. thrust for around 45 sec.

The next problem studied was stability of the WAC in vertical flight. A missile in vertical flight is obviously unstable in the sense that, if there is some small disturbance, gravity causes the trajectory to depart more and more from the vertical. There were two ways to assure vertical flight. The first and most direct method was to employ a gyro-stabilization system together with movable aerodynamic surfaces. For the desirable relatively small dimensions of a sounding rocket, however, the weight of such a system with its gyroscopes, servo-mechanisms and other auxiliary equipment was at the time so high as to make it a rather dubious method of solving the problem. The second approach was to launch the WAC at a sufficiently high speed so that deviation from the vertical was not of any great importance. This speed could be accomplished by using a second rocket to boost the WAC quickly to a velocity of about 400 ft. per sec. before it left a launching tower. It was estimated that the WAC needed to be guided in a tower for around 60 ft. and that launching acceleration should not exceed about 50 g.

The WAC was to be capable of carrying an instrument payload of 25 lb., which was to be lowered to the ground by parachute.

The above recommendations were accepted by the Ordnance Department, and design of the WAC with supporting

equipment was immediately initiated. Plans were also made for testing the WAC at White Sands Proving Ground.

The WAC, as finally constructed and tested (Fig. 1), had the following specifications [37 - 40]:

Overall length: 194 in.
Max. diameter of body: 12.2 in.
Three tail fins of 24 in. half span.
Gross weight: 665 lb.
Empty weight: 297 lb.
Red fuming nitric acid 286 lb.
Aniline-furfuryl alcohol mixture: 114 lb.
Air at 1900 psi. : 19 lb.
Motor thrust: 1,500 lb.
Thrust duration: 45 sec.
Impulse-weight ratio: 102 sec.

It was assembled by the Douglas Aircraft Co., Santa Monica, California, from components supplied by JPL's ORDCIT Project.

The sounding rocket was boosted from the launcher by means of a modified ballistite solid propellent rocket engine from an armament projectile called the TINY TIM which had the following specifications [37 - 40]:

Overall length: 96 in.
Max. diameter of body: 11.75 in.
Three tail fins, half span: 26 in.
Gross weight: 759 lb.
Weight of propellent: 149 lb.
Ave. thrust (sea level): 50,000 lb.
Nominal duration of thrust: 0.6 sec.
Impulse-weight ratio: 40 sec.

The launcher at White Sands Proving Ground consisted of a 77 ft. triangular structural steel tower, 6 ft. on a side, resting on a tripod 25 ft. high with a 26 ft. base, giving an overall height of 102 ft. [37 - 40]. The tower contained three launching rails set 120° apart to guide the WAC and its booster. The effective length of the rails was 82 ft. Details of the design of the launcher are given in Reference 40. It was built for the ORDCIT Project. A bombproof control house was constructed by the Ordnance Department 465 ft. from the launcher.

To check the flight characteristics of the WAC-booster combination, tests were made with a 1/5 scale model, called the BABY WAC. These were launched from a scaled-down launching tower at Camp Irwin, California, beginning 4 July 1945 [41]. One of the interesting aspects of these tests was the verification of the suitability of employing three instead of the traditional four tail fins. For some reason, rockets in the past and aerial bombs were equipped with four fins. Stewart, to save weight, proposed we use three but Ordnance 'experts' told us the WAC would then not be stable in flight. When he pointed out that arrows for ages had three fins and had performed very nicely, he was still doubted. The tests of the BABY WAC settled all arguments; the model behaved very well, as later did the three-finned full-scale WAC. The BABY WAC reached an altitutude of around 3,000 ft.

Since the WAC was expected to be used as a meteorological sounding rocket in locations that would be near populated areas, we decided to provide a 10 ft. parachute in the nose of the WAC to lower it to the ground at a velocity of around 70 ft. per sec. [37,42,43]. The parachute was to be released at the zenith of vertical flight. It was attached to the top of the propellent tanks and housed in the nose cone. The nose cone was attached to the WAC by means of three explosive pins inserted through the skirt of the nose cone into lugs welded on the tank head. The skirt was seated on a rubber ring seal-strip so that, at launching, atmospheric pressure was sealed in the nose and provided a force to push the nose away at the zenith of flight, where the outside pressure was practically zero.

Two schemes were to be tried to fire the explosive pins at zenith. The first used a gyroscope, the frame of which when the WAC turned through 90° was to close an electric circuit to the pins. The second scheme used a mechanical timing device to close the circuit at the predicted time of flight to zenith [37].

To check the flight characteristics of the WAC-booster combination, tests were made with a 1/5 scale model, called the BABY WAC. These were launched from a scaled-down

The Signal Corps provided radio sonde equipment with its own parachute to be installed in the nose cone, to be released at the same time as the parachute of the WAC [37]. It also provided weather information, including data obtained from balloons rising up to about 100,000 ft.

The WAC was tested at the White Sands Proving Ground, New Mexico, during the period 26 September to 25 October 1945, only nine months after I proposed the sounding rocket to Trichel in Washington, D.C. Details of the test programme can be found in References 37 to 44.

In 1936, I had placed on my office wall at Caltech a chart showing the aspects of a successful sounding rocket requiring attention. The dream had now become a reality, with an engineer in charge of each of these apsects. Key members of my WAC team were: M. M. Mills (Booster), P. J. Meeks (Sounding Rocket), W. A. Sandberg and W. B. Barry (Launcher and WAC nose), S. J. Goldberg (WAC Field Tests), H. J. Stewart (External Ballistics) and G. Emmerson (Photography).

A group photograph of most of the ORDCIT Project Personnel who participated in the test programme at White Sands is shown in Fig. 6. In all, 37 persons were involved, not including those concerned with preparations for the tests at JPL. The number of people in this programme indicated why the dreams of individuals and small groups of rocket enthusiasts in the 1920's and 1930's to design, construct and test a high altitude sounding rocket had little chance of success. Fortunately, most pioneers do not foresee all of the practical implications of their dreams. No doubt if they were able to do so, few new ideas would ever be tried.

The test programme proceeded step by step until we were confident that basic components were satisfactory. First, four rounds of the weight-adjusted TINY TIM booster alone were fired to check the booster, launcher and firing controls, and to give practice to radar and camera crews. Next, two dummy rounds of the WAC constructed of steel tubing filled with concrete were launched. These were followed by two WAC rounds with a partial charge of propellent to check behaviour of the liquid propellent rocket engine, the separation of the booster from the WAC and the operation of the nose cone release mechanism. Up to this point, all systems were 'go' except for the nose cone release mechanism, which failed both times. The partial charge WAC reached an altitude of around 28,000 ft. and difficulties were only encountered in tracking it with radar [37,44].

Radar tracking at this time was still in a rudimentary state of development. The troubles of the radar group from the Ballistic Research Laboratory at Aberdeen Proving Ground,

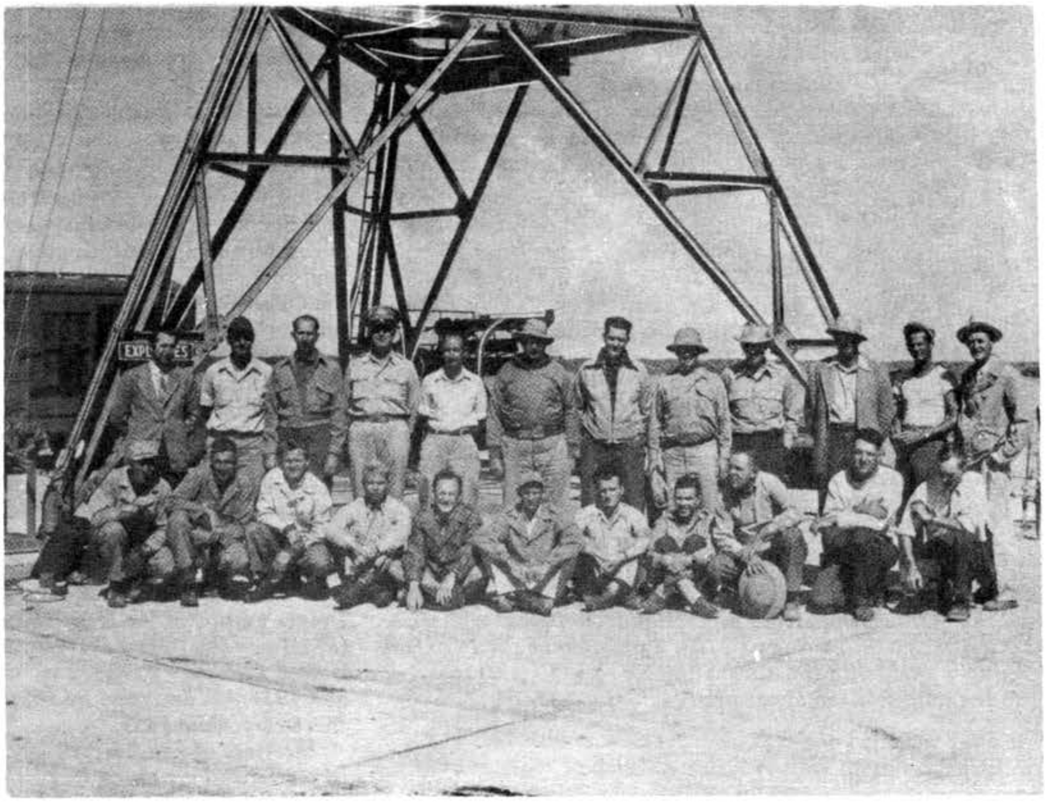


Fig. 6. WAC CORPORAL flight test crew, White Sands Proving Ground, New Mexico, U.S.A., October 1945.

Maryland, headed by L. A. Delsasso, did not interfere with his prowess as a poker player in games we played in the evenings when we did not go across the Rio Grande River to Juarez in Mexico or work on the WAC.

Our great day for the first flight of the WAC (Round 5) fully charged with propellent was 11 October 1945. It was a clear day. We craned our necks to watch the WAC's smoke trail until the engine stopped at around 80,000 ft. On the basis of radar tracking data for the 6th round of the WAC, it was estimated that the maximum altitude reached was between 230,000 and 240,000 ft. The total time of flight was about 450 sec. or 7.5 minutes. The velocity of the WAC at the end of burning was about 3,100 ft/sec, and the impact point of the first round was about 3,500 ft. from the launcher, which meant that the WAC had maintained a very satisfactory vertical path. Success!

I was the sole member of the original GALCIT Rocket Research Group of 1936 to experience the culmination of its hopes after many zig-zaggings in rocket development over the ensuing period of 10 years. It is difficult to describe my feelings as I watched the sounding rocket soar upward. One can think of many things in a few minutes and one of my thoughts was that I could now turn my mind to other goals in a world full of both fascinating technological possibilities and of desperate social problems.

Six charged rounds were fired during this 1945 programme. In round 7, the nose cone release mechanism functioned prematurely shortly after the WAC left the launcher but it continued in vertical flight. The parachute did not lower the WAC to the ground successfully in any of these flights, for it was either not released, released prematurely or torn off during descent. This did not surprise us, as there was very little prior experience on the behaviour of parachutes opened at high altitude. Even after the parachute failed the first time, many of us remained standing in the impact area because Stewart assured us that the probability of being struck was very small. Even so, we were startled to see one impact take place about 200 yards from where we were standing.

When the center of gravity of the WAC was too far forward, it went into a flat spin during its fall to the ground and, as a result, it struck the ground at greatly reduced speed. Radar tracking gave a minimum of data to permit the height reached by the WAC to be calculated. On most rounds it failed completely. That radar can now be used to map the surface of a distant planet seems incredible.

The tests of the WAC CORPORAL showed that the design features we chose for a practical sounding rocket of reasonable cost were correct. The use of a booster rocket and an adequate launching tower circumvented the need of a guiding system. The use of a storable liquid propellent engine simplified launching procedures compared to the use of LOX engines [45,46].

It is a tradition at JPL to be conservative and unsensational in making proposals when dealing with problems involving many unknowns. Thus, we set the altitude to be reached by the WAC to be above 100,000 ft. In view of the fact that no liquid propellent engine sounding rocket before had reached more than a few thousand feet that seemed quite ambitious. The fact that the WAC so far exceeded our first theoretical estimates was primarily due to a reduction of the empty weight and to the increased amount of propellent carried by the WAC.

In March 1946, plans were initiated for the design and construction of the WAC CORPORAL B, with Meeks as Project Co-ordinator. The modified sounding rocket was to incorporate recommendations resulting from the tests of October 1945 and from those scheduled for May 1946, and a lighter

weight redesigned engine and propellent tanks to increase the propellent-to-gross weight of the first design. A report on the tests of the WAC B at White Sands Proving Ground in December 1946 and in February-March 1947 can be found in Ref.47.

The results and know-how obtained with the WAC CORPORAL were incorporated in its successor, the AEROBEE, which was designed and constructed by Aerojet and assembled by the Douglas Aircraft Company. The project, sponsored by the Navy Bureau of Ordnance, was carried out under the technical direction of the Applied Physics Laboratory of Johns Hopkins University, with James A. Van Allen as supervisor. The contract to Aerojet was awarded on 17 May 1946 and the first full-scale AEROBEE was launched at White Sands on 24 November 1947 [33,47].

Numerous variations of the basic WAC design have been constructed in the USA and in other countries and have been used for high-altitude research since 1948 [33].

The Corporals

A major objective of the ORDCIT Project, as described earlier, was the development of a remotely controlled missile to carry an explosive load of 1,000 lb. for a distance of up to 150 miles, with a dispersion not in excess of 2% and at a velocity sufficient to afford protection from fighter aircraft. Tsien outlined on 14 August 1944 a programme for an experimental missile (with the designation XF36 L 20,000) that had the following tentative specifications [48]:

Gross weight: 5 tons.
Diameter: 36 in.
Rocket thrust: 20,000 lb.
Thrust duration: 60 sec.
Sp. propellent cons.: 0.005 sec.
Stabilization: fins.
Range: 30 to 40 miles.

At that time, only a storable liquid propellent engine of the type developed by JPL could meet these specifications and the thrust required was much higher than any motor constructed in America up to that time. The largest uncooled motor that had been tested at JPL delivered about 6,000 lb. thrust.

We were now also confronted for the first time with the idea of launching a large rocket vertically without a booster rocket and a guiding launcher. I do not believe that we knew in early 1944 that the V-2 was launched in this way. There was considerable scepticism voiced over the possibility of keeping a missile in a vertical position solely by means of tail fins and control surfaces as it slowly lifted off the ground. On the other hand, it was evidently not feasible to boost at high acclerations a lightly constructed vehicle of the dimensions required.

Detailed analysis of the various components and of the flight characteristics of the missile was immediately started. The design and testing of the 20,000 lb. thrust nitric acid-aniline type engine was initiated under the supervision of Seifert. It was decided to develop simultaneously two engines, an engine with a gas-pressure propellent supply system, with which much experience had already been gained, for installation in a missile designated the CORPORAL E; and an engine with a turbine-driven pump propellent supply system engine (turborocket) for installation in the CORPORAL F. The development of a turborocket engine, which had been underway for some time under N. van de Verg, was speeded up [2].

Facilities for testing the complete CORPORAL engines were constructed at the Muroc Flight Test Base, California, of the Air Technical Service Command. They were completed in June 1945 and operated under the direction of W. B. Powell [12].

When Dunn became Assistant Director in 1944, he devoted much of his effort to the CORPORAL programme. In the summer of 1945, Summerfield returned from Aerojet and assumed the role of co-ordinator [45]. Fabrication of components of the missiles was sub-contracted to machine shops in the Southern California area. The construction of components became the main bottleneck in the programme because the ORDCIT Project at this time could not compete with priorities assigned to other production orders of the Armed Forces for the final year in the Pacific Theatre of Operations [12]. Information on work carried out by the end of 1946 on the aerodynamics and mechanical design of the CORPORALS can be found in the archives of JPL [48-64] (Fig.7).

The problems of remotely guiding and controlling a missile were entirely new to JPL and, furthermore, no work had been carried out on aircraft autopilot systems at the Caltech Guggenheim Aeronautical Laboratory. Upon the suggestion of Skinner, consideration was given to making contractual arrangements on CORPORAL guidance development with either C. Stark Draper's group at the Massachusetts Institute of Technology (M.I.T.) or the Sperry Gyroscope Company [12]. The evolution of aerospace guidance technology at MIT between 1935 and 1951 was discussed by Draper in the paper presented at this Symposium [65].

Meetings of von Kármán and Trichel on 29 July 1944 and of Martel and me on 24 August with Sperry personnel led to a contract between JPL and Sperry for the co-operative development of the CORPORAL guidance system [12]. I especially enjoyed making the acquaintance of Gifford E. White of Sperry, who with Pickering laid the basis for the guidance system [66]. C. B. Millikan, who had wide experience in aerodynamics, devoted much time to getting this programme underway. Primarily through his efforts Pickering joined the staff

Fig. 7. Launching of the CORPORAL guided missile at White Sands Proving Ground, New Mexico, U.S.A., during test programme begun in 1952.

of JPL in August 1944 to establish the Remote Control Section, with Frank Lehan as his principal assistant. Information on the work carried out under this Section up to the end of 1946 can be found in the archives of JPL [45,66].

Solid Propellent Research and Applications

Sponsorship of solid propellent research was taken over by the ORDCIT Project from the Air Force Materiel Command on 1 July 1944 [2]. By this time, JPL had made the following fundamental contributions to the design and construction of long-duration solid propellent engines [2]:

(a) *Theory*

1. Von Kármán-Malina theory of constant-thrust long-duration engines (1940).

(b) *Propellent development*

1. Parsons' break-away from ballistite and use of an amine black powder (1940).

2. Parsons' introduction of perchlorates as an oxidizer (1942).

3. Parsons' introduction of asphalt as a fuel-binder with perchlorates. Invention of a castable case-bonded composite propellent charge (1942).

(c) *Engine component design*

1. Parsons' design of a restricted burning (case-bonded) propellent charge with amine black powder (1940).

2. Design by Malina and Mills of a safety pressure-relief valve (1942).

3. Mills' review of various types of burning surfaces of a charge and theoretical confirmation that the surface of a cigarette type burning charge was stable (1943).

After the successful JATO development with the asphalt-perchlorate propellent in 1942, effort was primarily directed, under the supervision of Mills, to finding a fuel-binder for the perchlorate superior to asphalt. In 1944, Charles Bartley joined Mills' group and in 1945 introduced as a replacement for asphalt a castable elastomeric material, polysulfide rubber, produced by the Thiokol Chemical Corporation. A report on the development of this propellent can be found in Ref. 67. The polysulfide rubber compared to asphalt produced a propellent much better both as regards storage temperature limits and hardness at high atmospheric temperatures. The latter property was especially important in the design of high thrust engines requiring an internal burning surface rather than a cigarette-burning surface charge [68]. Since at this time only Aerojet in America was producing composite solid propellent engines, I drew the company's attention to the asphalt replacement but it was already interested in a similar material made by the General Tire and Rubber Co. I believe it was at the urging of the Ordnance Department that the Thiokol Chemical Corporation entered the field of composite solid propellents with the new fuel-binder found at JPL.

After obtaining the experience with the composite solid propellent missiles PRIVATES A and F, studies were initiated at JPL in 1946 on larger missiles using in particular the polysulfide rubber-perchlorate type of propellent. The results of these studies [69] led eventually to the design of the guided missile called the SERGEANT.

The Laboratory followed closely developments with other types of solid propellents, especially ballistite, used in high-thrust short-duration engines suitable for boosters. Available engines were modified to meet special requirements for boosting the PRIVATES and the WAC CORPORALS.

Considerable research was also conducted by the Solid Propellent Rocket Section, under Bartley, and the Propellent Section, under N. Kaplan and later under S. A. Johnston, on gas generation systems to replace stored gas for feeding liquid propellents to rocket motors. Our optimism that such a system could be developed quickly proved to be unfounded.

Application of Rocket Propulsion for Extraterrestrial Space Exploration

I have described the background to the initiation of rocket research at Caltech in my first memoir on the GALCIT Rocket Research Project, 1936-38 [1]. Space travel, which was the goal of this Project, was not stressed after we realized that existing rocket technology was a long way from providing the means for accomplishing such a goal. It is true that journalists published stories interpreting our studies of sounding rocket performance and preliminary rocket engine experiments as heralding a planned landing on the Moon by Caltech. It was not until after work on the CORPORAL was initiated in early 1945 that studies were resumed that had been put aside in 1938 in order to develop rocket engines for aircraft applications.

The WAC could be considered as a two-step rocket vehicle. Summerfield and I began, I believe in the summer of 1945, a more detailed analysis of such vehicles, with a re-evaluation of the feasibility of a rocket payload being launched at sufficient velocity to escape the gravitational field of the Earth. The analysis was based on the state of rocket technology at that time and included a discussion of the possible use of a nuclear energy rocket engine [70]. The analysis led to the Malina-Summerfield criterion for step-rockets, which states that the optimum step-rocket will be one in which the ratio of the mass of payload for each step to the mass of the step propelling the payload is the same (the payload for step one is the mass of all succeeding propulsion steps plus the mass of the final useful payload).

We calculated as an example a step-rocket to launch to escape velocity a useful payload consisting of an instrument for measuring cosmic ray intensity with a radio beacon transmitter for sending the data back to Earth. Obviously, if a useful payload could be launched to escape velocity, it could also be placed in orbit around the Earth, at least as regards rocket propulsion. America's first satellite, EXPLORER I, on 31 Jan. 1958, carried a cosmic ray instrument and the payload weight was about the same as we had chosen.

I presented on 3 January 1946 in Washington, D.C., the results of our study as well as the high points of achievements at JPL, to the War Equipment Board of the Army, which was headed by General Joseph W. Stilwell. As I recall, the Board made little comment on the implications of the possibility of launching a man-made object away from the Earth. Stilwell is quoted in Ref. 71 as having written the following in his diary in regard to his assignment to the Board: 'I am eminently suited to do something else and would as lief sit on a tack'.

We had made conservative assumptions in our 'escape' analysis, especially as regards propellent specific impulse and

structural weights of vehicle components. An example we gave of 5-step rocket to launch a 10 lb. payload to escape velocity was estimated to weigh 3,000,000 lb. for the nitric acid-aniline propellent combination and 450,000 lb. for oxygen and ethanol. It was difficult for almost anyone in 1946 to imagine meeting the engineering problems and cost of constructing such rockets.

The analysis we made was correct, as was pointed out in 1959 by J. E. Froehlich [72]. However, between 1946 and 1959 improvements in engine and structural design permitted the gross weight required to launch a payload to escape velocity to be reduced by a factor of over 400. This is certainly an amazing demonstration of the possibilities of technological research and development when there is a will to support them.

The following summer I returned to London to undertake, starting on 7 July 1946, a second mission in Europe for the Army Ordnance Department in the office of Colonel Reed, Assistant Military Attache. My mission was much broader than it had been in 1944, for I also was asked to report on matters related to science and technology outside the domains of rocket propulsion and missile design. I remained in Europe until December 1946 and during this time I saw von Kármán several times and discussed with him aspects of the post-war situation, especially as they would affect his and my plans for the future.

I discussed our 'escape' study at a meeting of the British Interplanetary Society (BIS) in London and presented a paper on it at the Sixth International Congress for Applied Mechanics in Paris [70]. The members of the BIS who were at the meeting were not very happy when I said that at this time it should be possible to land a man on the Moon, provided he was sent up in two halves in separate rockets, without the offer of a return trip to Earth.

One of the results of our study was Summerfield's suggestion that a programme be initiated to launch a two-step rocket vehicle consisting of the WAC CORPORAL boosted by the V-2. Initiation of this programme at JPL was authorized by the Ordnance Department in October 1946 and the vehicle was designated as the BUMPER WAC. A photograph of the rocket vehicle is shown in Fig. 8. It was successfully launched at White Sands Proving Ground on 24 February 1949 and the WAC reached an altitude of 244 miles [73]. Thus the WAC became the first positively recorded man-made object to enter extra-terrestrial space and the 'space-age' could be said to have been opened in America in 1949. On 24 July 1950, a BUMPER WAC was launched as part of the first missile launching programme from Cape Canaveral (now called Cape Kennedy).

While Summerfield and I were concluding our 'escape' study, the Navy Bureau of Aeronautics on 12 December 1945 made a contract with JPL for studies of a rocket vehicle for launching an Earth satellite. The work of the Navy and of JPL on this programme can be found in a detailed historical paper by R. Cargill Hall [74]. Unfortunately, for the reasons he puts forward, the Navy dropped the programme in 1947.

A summary of the basic aspects of the phy s of space flight as understood at JPL in 1946 can be fou. d in a paper by Seifert, Mills and Summerfield [75]. A Guided Missile a Upper Atmosphere Symposium was held at JPL from 13 to 16 March 1946, in which leaders of research on relevant subjects from all parts of the USA participated [76].

Concluding Remarks

There are many areas of research conducted unde. the ORDCIT Project that I have not gone into in any detail, for example, work on materials, chemistry of propellents, ramjet design, telemetering of data from missiles in flight and remote control of missiles. The main reason is that my role in these domains was mainly of an administrative character and, therefore, those that led the actual work would be able to shed light on them that cannot be gleaned from formal technical reports.

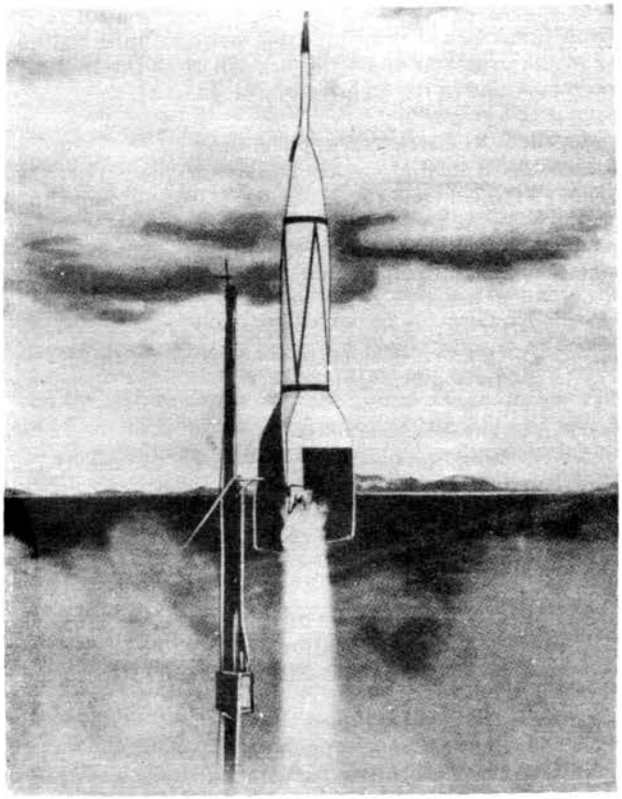


Fig. 8. Launching of the BUMPER WAC rocket vehicle consisting of V-2 (first stage) and WAC CORPORAL (second stage) at White Sands Proving Ground, New Mexico, U.S.A., during the 1948-1949 period.

The preparation of my three memoirs on the origins and work of JPL between 1936-46 has heightened my appreciation of the difficulties confronting those who write on the history of technology. Not only are demands made on authors to understand the technical matters of a development but interpretations are expected of them that require a historical perspective on a world-wide scale, which cannot be obtained only from chronologies and formal technical, published and unpublished, reports. If in addition, authors wish to attract the attention of the lay public, then, if the greatest care is not taken, approximations to the truth recede further and further into space to be replaced by myths.

REFERENCES

1. F. J. Malina, Memoir on the GALCIT Rocket Research Project, 1936-1938, *Proceedings 1st Int. Symp. on History of Astronautics*, Int. Academy of Astronautics, 6 June 1967. To be published in the *Annals of Flight*, Smithsonian Institution, Washington, D. C. Abridged version in *Engineering and Science*,

31, 9 (1968). Also in Russian in *From the History of Rockets and Astronautics* (Moscow: Publishing House Nauka, 1970).
2. F. J. Malina, Memoir: The U.S. Army Air Corps Jet Propulsion Research Project, GALCIT Project No. 1, 1939-1946. *Proceedings 3rd Int. Symp. on History of Astronautics*, Int. Acad. of Astronautics, 10 October 1969. To be published in the *Annals of Flight*, Smithsonian Institution, Washington, D.C.
3. Th. von Kármán with L. Edson, *The Wind and Beyond* (Boston: Little, Brown, 1967).
4. F. J. Malina, Short History of Rocket Propulsion up to 1945, *Jet Propulsion Engines, High Speed Aerodynamics and Jet Propulsion*, ed. O. E. Lancaster, Vol. XII (Princeton: Princeton University Press, 1959).
5. A. B. Christman, *Sailors, Scientists and Rockets*, (Washington, D. C.: U.S. Government Printing Office, 1971).
6. S. D. Felkin, Development of the Do. Gerat-rockets and athodyds, British Intelligence Rep. No. GB-AM, A.I. (K), R-184 A., 1943.
7. S. D. Felkin, The application of reaction propulsion devices to projectiles and aircraft, British Intelligence Rep. No. GB-AM, A.I. (K), R-227 A, 1943.
8. S. D. Felkin, The application of reaction propulsion devices to projectile and aircraft, British Intelligence Rep. No. GB-AM, A.I. (K), R-246 B, 1943.
9. D. Irving, *The Mare's Nest* (Boston: Little, Brown, 1965) pp. 45-48, 53-55, 60-61.
10. H. S. Tsien, F. J. Malina, A Review and Preliminary Analysis of Long-range Rocket Projectiles, *JPL-GALCIT*, Memo. No. JPL-1, 20 Nov. 1943. Summary in *Collected Works of Theodore von Kármán*, Vol. IV, (London: Butterworth Scientific Pub., 1956) p.206.
11. Th. von Kármán, Memorandum on the Possibilities of Long-range Rocket Projectiles, *JPL-GALCIT*, Memo. No. JPL-1, 20 Nov. 1943. Summary in *Collected Works of Theodore von Kármán*, Vol. IV (London: Butterworth Scientific Pub., 1956) p. 206.
12. R. C. Miles, The History of the ORDCIT Project up to 30 June 1946, JPL Library document No. ARC-27, 1946, (Unpublished).
13; Letters to the author from Robert B. Staver dated 17 and 26 August 1971.
14. Th. von Kármán with contributions from F. J. Malina, M. Summerfield and H. S. Tsien, Comparative Study of Jet Propulsion Systems as Applied to Missiles and Transonic Aircraft, *JPL-GALCIT*, Memo. No. JPL-2, 28 March 1944. Summary in *Collected Works of Theodore von Kármán*, Vol. IV (London: Butterworth Scientific Pub., 1956) p.209.
15. F. J. Malina, Origins and First Decade of the Jet Propulsion Laboratory, in *History of Rocket Technology*, E. M. Emme, ed. (Detroit: Wayne State Univ. Press., 1964). Also in *Spaceflight*, 6, 160 and 193 (1964).
16. F. J. Malina, Excerpts from letters written home between 1936 and 1946. (Unpublished).
17. 'Bible' of the GALCIT Rocket Research Project, Collected Papers by F. J. Malina, H. S. Tsien, J. W. Parsons, A.M.O Smith, W. Bollay, Calif. Inst. of Tech., June 1937. (Unpublished).
18. F. J. Malina and A. M. O. Smith, Flight Analysis of a Sounding Rocket, *Jrn. Aeronautical Sciences*, 5, 199 (1938).
19. H. S. Tsien and F. J. Malina, Flight Analysis of a Sounding Rocket with Special Reference to Propulsion by Successive Impulses, *Jrn. Aeronautical Sciences*, 6, 50 (1938).
20. F. J. Malina and H. J. Stewart, Considerations of the Feasibility of Developing a 100,000 ft. Altitude Rocket (The WAC CORPORAL), *JPL-GALCIT*, Memo, JPL 4-4, 16 January 1945 (Unpublished).
21. Research Programme for the First Type of Longe-range Jet Propelled Missile (XF 10S 1000-A and XF 10S 1000-B), *JPL-GALCIT*, Memo. No. 4-1, 2 August. 1944. (Unpublished).
22. W. A Sandberg, W. B. Barry, R. S. McLean, Design of PRIVATE A, Facilities for Handling the Missile and Launcher, *JPL-GALCIT*, Rep. No. 4-1, 8 May 1945. (Unpublished).
23. M. M. Mills, Thrust and Inertial Characteristics of Rocket Missile XF 10S 1000-A, PRIVATE A, *JPL-GALCIT*, Rep. No. 4-2, 19 March 1945. (Unpublished).
24. S. J. Goldberg, Firing Tests of PRIVATE A at Leach Spring, Camp Irwin, California, *JPL-GALCIT*, Rep. No. 4-3, 14 March 1945. (Unpublished).
25. W. Z. Chien, The Trajectories of the Rocket Missile XF 10S 1000, *JPL-GALCIT*, Prog. Rep. No. 4-1, 3 November 1944. (Unpublished).
26. C. C. Lin, The Exterior Ballistics of PRIVATE A from Analyses of Firing Tests, *JPL-GALCIT*, Rep. No. 4-4, 1945 (Unpublished).
27. W. A. Sandberg and W. B. Barry, Design of PRIVATE F, Facilities for Handling the Missile and Launcher, *JPL-GALCIT*, Rep. No. 4-5, 14 July 1945. (Unpublished).
28. S. J. Goldberg, Firing Tests of PRIVATE F at Hueco Range, Fort Bliss, Texas, April 1 to April 13, 1945, *JPL-GALCIT*, Rep. No. 4-7, 10 May 1945. (Unpublished).
29. C. B. Millikan, Scale Model Flight Tests of ORDCIT Winged Missiles, *JPL-GALCIT*, Memo. No. 4-6, 8 April 1945. (Unpublished).
30. F. J. Malina, Is the Sky the Limit: Ordnance Rockets Demolish the Barriers of Space, *Army Ordnance*, 31, 45 (July-Aug. 1946).
31. R. H. Goddard, A method of Reaching Extreme Altitudes, *Smithsonian Misc. Collections*, 71, No. 2, 1919.
32. R. H. Goddard, The Possibilities of the Rocket in Weather Forecasting, *Proc. Nat. Acad. Sciences*, 6, 493 (1920).
33. W. R. Corliss, *NASA Sounding Rockets, 1958-1968*, (Washington, D. C. Supt. of Docs., U. S. Govt. Printing Off., 1971).
34. M. Lehman, *This High Man*, (New York: Farrar, Straus, 1963).
35. R. H. Goddard, Liquid-propellent Rocket Development, *Smithsonian Misc. Collections*, 95, No. 3, (1936).
36. M. K. Tikhonravov, From the History of the Construction of the First Soviet Liquid Fuel Rockets, *Proc. 1st Int. Symp. on History of Astronautics*, Int. Acad. of Astronautics, 6 June 1967. To be published in the *Annals of Flight*, Smithsonian Institution, Washington, D. C. Also in Russian in *From the History of Rockets and Astronautics* (Moscow: Publishing House Nauka, 1970).
37. F. J. Malina, Development and Flight Performance of a High Altitutude Sounding Rocket, the 'WAC CORPORAL', *JPL-GALCIT*, Rep. No. 4-18, 24 Jan. 1946. (Unpublished).
38. P. J. Meeks, Design of 1500 lb. Rocket Motor and Selection of Control Valves for the WAC CORPORAL, *JPL-GALCIT*, Prog. Met. Rep. No. 4-12, 8 May 1945.(Unpublished).
39. P. J. Meeks, R. O. Terbeck, Design, Performance and Servicing of the WAC CORPORAL Propulsion System *JPL-GALCIT*, Rep. No. 4-20, 5 April 1946. (Unpublished).
40. W. A. Sandberg, W. B. Barry, Design and Fabrication of the WAC CORPORAL Missile, Booster, Launcher and Handling Facilities, *JPL-GALCIT*, Rep. No. 4-21, 19 Feb. 1946. (Unpublished).
41. A. E. Puckett, J. B. Kendrick, O. E. Bartley, Design and Testing of a 1/5-scale of the WAC CORPORAL, *JPL-GALCIT*, Rep. No. 4-12, 18 July 1945. (Unpublished).
42. W. Z. Chien, Lateral Dispersion of the WAC CORPORAL, *JPL-GALCIT*, Prog. Rep. No. 4-10, 16 May 1945. (Unpublished).
43. P. L. Chambre, F. J. Malina, Considerations on the Descent of a Parachute from High Altitude, *JPL-GALCIT*, Prog. Rep. No. 4-24, 26 July 1946. (Unpublished).
44. S. J. Goldberg, Field Preparation, Firing Procedure and Field Results for the WAC CORPORAL, *JPL-GALCIT*, Rep. No. 4-22, 30 Nov. 1945. (Unpublished).
45. Minutes of Bi-Weekly Conferences, ORDCIT Project, JPL-4, 27 June 1944 - 18 July 1946. (Unpublished).
46. P. J. Meeks, F. G. Denison, Jr., R. F. Rose, Design, Development and Field Tests of the WAC B Sounding Rocket, JPL Rep. No. 4-41, 15 Dec. 1947. (Unpublished).
47. H. E. Newell, Jr., *High Altitude Rocket Research* (New York: Academic Press, 1953).
48. C. C. Lin, Control Forces Required for the Stable Vertical Ascent of a Jet-Propellent Missile, *JPL-GALCIT*, Prog. Rep. No. 4-3, 8 Nov. 1944. (Unpublished).

49. H. J. Stewart, Static and Dynamic Stability Estimates for the CORPORAL, *JPL-GALCIT*, Prog. Rep. 4-4, 10 Nov. 1944. (Unpublished).
50. H. J. Stewart, Subsonic Wind Tunnel Tests on Model of a Jet Propelled Missile and Certain Applications to Missiles XF 30L 20,000 and XF 10S 1000, *JPL-GALCIT*, Prog. Rep. 4-5, 1 Dec. 1944. (Unpublished).
51. W. Z. Chien, An Approximate Method of Integration of Ballistic Equations, *JPL-GALCIT*, Prog. Rep. No. 4-6, 14 Dec. 1944. (Unpublished).
52. W. Z. Chien, The Trajectories of the Missile XF 30L 20,000 (Corporal), *JPL-GALCIT*, Prog. Rep. 4-7, 19 Jan. 1945. (Unpublished).
53. C. C. Lin, Stability of the CORPORAL with Time-Lag in the Control System, *JPL-GALCIT*, Prog. Rep. 4-8, 23 Jan. 1945. (Unpublished).
54. P. L. Chambre, The Surface Temperature of a Missile in High Speed Flight, *JPL-GALCIT*, Prog. Rep. 4-13, 20 May 1945. (Unpublished).
55. C. C. Lin, On the Accuracy of a Long-range Jet Propelled Missile, Part 1: Asymetrical Frequency Distribution of Impacts, *JPL-GALCIT*, JPL Rep. 4-13, 11 Sept. 1945. (unpublished).
56. C. C. Lin, Supersonic Lift and Moment Characteristics of a Shell with a Conical Nose, *JPL-GALCIT*, Rep. JPL-14, 9 Oct. 1945. (Unpublished).
57. W. Z. Chien, Estimated Values of the Aerodynamic Co-efficients of the Corporal E, *JPL-GALCIT*, Prog. Rep. 4-20, 13 Feb. 1946. (Unpublished).
58. H. J. Stewart, The Linearized Theory of Supersonic Flow, *JPL-GALCIT*, Rep. JPL-26, 22 Feb. 1946. (Unpublished).
59. R. B. Canright, The development of a Turborocket Gas-generating Chamber, *JPL-GALCIT*, Rep. JPL-27, 21 May 1946. (Unpublished).
60. W. B. Powell, Description of Facilities for Testing Large Scale Liquid-Propellent Rocket Motors at the ORDCIT Test Station, Muroc, California, *JPL-GALCIT*, Rep. JPL-25, 26 Feb. 1946. (Unpublished).
61. W. Z. Chien, Wave Drag of a Projectile Nose at a Supersonic Velocity by the Kármán-Moore Method, *JPL-GALCIT*, Rep. No. 4-24, 19 March 1946. (Unpublished).
62. A. G. Mowbray, The Trajectories of the Corporal E with One-Third of Normal Propellent Charge and with Lift Due to Constant Elevator Deflection, *JPL-GALCIT*, Prog. Rep. 4-22, 28 Feb. 1946. (Unpublished).
63. A. G. Mowbray, Lift, Pitching Moment and Pitching Hinge Moment for the Corporal E, *JPL-GALCIT*, Prog. Rep. 4-28, 8 Aug. 1946. (Unpublished).
64. J. B. Kendrick, Model Tests of the Launching Characteristics of the Corporal E, *JPL-GALCIT*, Prog. Rep. 4-21, 15 Oct. 1946. (Unpublished).
65. C. S. Draper, The Evolution of Aerospace Guidance Technology at the Massachusetts Insitute of Technology, 1935-1951, *Proceedings 5th Int. Symp. on History of Astronuatics*, Int. Academy of Astronautics, 23 Sept. 1971. (To be published).
66. H. Harris, W. Harcum, G. E. White, Control System for the Corporal E, *JPL-GALCIT*, Prog. Rep. 4-18. (Unpublished).
67. C. E. Bartley, Development of a Castable Solid Propellent Having a Polysulfide Rubber Fuel Base, *JPL*, Prog. Rep. 4-37, Aug. 1947. (Unpublished).
68. *Jet Propulsion*, Hsueh-Shen Tsien, ed., *JPL- GALCIT*, 1946. (Unpublished).
69. M. Summerfield, J. I. Shafer, H. L. Thackwell, Jr., C. E. Bartley, The Applicability of Solid Propellents to High-Performance Rocket Vehicles, *JPL*, Memorandum 4-17, 10 Oct. 1947. (Unpublished).
70. F. J. Malina, M. Summerfield, The Problem of Escape from the Earth by Rocket, *Jrn. Inst. Aero. Sci.*, **14**, 471 (1947).
71. B. W. Tuchman, *Stilwell and the American Experience in China, 1911-45*, (New York: MacMillan, 1970) p. 523.
72. J. E. Froehlich, Capabilities of Multistaged Chemical Rocket Systems, *Inst. of Aero. Sci.*, Rep. 59-82 (1959).
73. R. C. Hall, A Selective Chronology of GALCIT-JPL Developments, 1926-1950, *JPL*, 8 Sept. 1967. (Unpublished).
74. R. C. Hall, Earth Satellites, A First Look by the United States Navy in the 1940's, *Proceedings Fourth History Symposium*, Int. Acad. of Astronautics, 9 Oct. 1970. (To be published).
75. H. S. Seifert, M. M. Mills, M. Summerfield, Physics of Rockets: Dynamics of Long Range Rockets, *Amer. Jrn. Physics.*, **15**, 255 (1947).
76. Abstracts of Papers presented at the Guided Missiles and Upper Atmosphere Symposium held 13-14 March 1946 at the Jet Propulsion Laboratory, GALCIT, *JPL-GALCIT*, Pub. No. 3 (1946). (Unpublished).

NEXT MONTH

The January 1974 issue of *Spaceflight* will include the first part of a major feature on the Mariner mission to Venus and Mercury. We shall also be reviewing the Large Astronomical Telescope, a major payload of the Space Shuttle, and continuing our major feature 'Children of the Dawn' on the theme: The Case for Asteroidal Missions. There will also be a review of major European space projects and another Skylab feature.

1974 SUBSCRIPTIONS

Members are reminded that the 1974 subscriptions will fall due for renewal on 1st January, the rates being as follows:

	Sterling	*US Dollars*
Student Members	£4.50	$12.50
Members	£5.50	$15.50
Senior Members	£6.00	$17.00
Associate Fellows	£6.50	$18.50
Fellows	£7.00	$20.00

The above fees include the receipt of *one* of the Society's publications, ie the *Journal* or *Spaceflight*. A further £4.50 ($12.50) should be added where members wish to receive *both* publications.

The Student Member rate of £4.50 ($12.50) applies only to Members under the age of 21.

Fellows, Associate Fellows, Senior Members, and Members who have attained the age of 65 years on 1 January 1974 can, if they wish, claim a reduction of £1 from their annual subscriptions.

Remittances should now be sent as soon as possible to:
The British Interplanetary Society
12 Bessborough Gardens, London, SW1V 2JJ.

SPACEFLIGHT

Volume XV
1973

Editor: K. W. GATLAND, F.R.A.S., F.B.I.S.

Published by the British Interplanetary Society
12, Bessborough Gardens, London, SW1V 2JJ.

List of Contents

MAIN ARTICLES

FEATURES

REVIEWS

'Spaceflight' Binders

I should be most grateful if you would inform me if a binder is produced by you for the purpose of filing back copies of *Spaceflight*. If none is produced by you, I should be grateful for your recommendations.

C. J. MORRIS

(We do not produce any loose-leaf binders. Permanent binding can be undertaken by any local bookbinders. Details of these can be found in the local classified telephone directories i.e. the 'Yellow Pages' – Ed.)

Extraterrestrial Interests

For a long time I have wanted to write on the possibilities of extraterrestrial life for the general reader but now Dr. Molton has done the job for me. His article is, in my opinion, one of the best I have ever seen on the subject. In many respects it reminds me of Clarke's monumental book *The Exploration of Space;* a book I acquired as a poor college boy in 1957 and absorbed every bit of it as a dry sponge!

I want to take the opportunity to thank you very much for your excellent publications and activities. To put it short, I am most sorry for not becoming a member of the BIS much earlier.

REYNIR EYJOLFSSON

Apollo 11 Recording

For a long time I have been trying to buy or borrow a tape-recording of the entire APOLLO 11 MOONWALK (July 21st 1969). Neither NASA nor the US National Audiovisual Center can help me, and I now think that my only hope is to find someone (possibly another BIS member) who would consider lending me such a tape-recording. Can you make any suggestions, or do you know any member who could help me?

GEOFFREY BOWMAN

Interplanetary Appropriations?

In a recent article I came across a reference to Baron Philippe de Rothschild, to the effect that the Baron had purchased a planet (sic) called Phillipa. Probably what the journalist meant was an asteroid or some other such small body.

What is the technical – or, I should say – legal position in the case of someone who wishes to lay claim on such a body? What bodies are available, under current law, for 'purchase'? What would be the statutory body concerned? How would one arrive at an estimate of the value of these bodies.

GEORGE HAY

CYRIL HORSFORD replies:-

Whoever purported to sell Baron Phillipe de Rothschild a planet or asteroid would appear to have collected the money under false pretences. International law is now quite clear since the United Nations Resolution 1721 in December 1961, and the subsequent U.N. Space Treaty of January 1967 (Article 3), that outer space, including the Moon and other celestial bodies, is not subject to national appropriation by means of use or occupation or by any other means. This, of course, includes private ownership.

There is thus no authority on Earth which can grant a purchase or lease of any celestial body, which are deemed to be the province of all mankind (Article 1), and perhaps indeed of some alien species as well. As Man explores deeper into space, and establishes bases on celestial bodies, some rights of jurisdiction over the base itself (see Articles 8 and 12 of the Space Treaty 1967) and ownership of any minerals found may have to be provided for, but it is likely that the general principle that states, corporations or individuals cannot claim sovereignty over such bodies will remain, and this will almost certainly apply also to any asteroid which is large enough to be considered as such, and not merely as debris.

There is no law against a planet or celestial body being named after an individual by common consent, in the manner of Halley's Comet or various features on the Moon, and this may be to what the journalist was referring.

Postal Shredders

I received my February copy of *Spaceflight* but only just. Two sides of the envelope were completely torn open and the magazine was simply folded inside the tattered remnant like a book inside a dust cover. I was concerned about this and asked my secretary whether much of the mail arrives like this. She replied that more and more mail was being delivered in this condition.

DR. B. A. GOODEN

Souvenir Hunters

I enclose a cheque for a car badge and a lapel badge. The car plaque was taken by an enthusiast whilst I was on holiday.

M. J. SUGDEN

(It happens to name-plates on the Society's front door, too! –Ed.)

New Zealand Interplanetary Society

In 1963, a small group in Christchurch decided to attempt resurrecting the New Zealand Interplanetary Society which ran from the end of 1953 for about 18 months, and suffered during a UFO 'invasion'. Little real progress toward founding an active Society has been made; in part, the existence of many active astronomical societies (28 at last count) in this country might be some major factor. However, we now have a nucleus of about 55 and the infrequent circulars which we issue serve to keep us in contact.

TREVOR CROSS

Jammy!

I am sending you a photograph of what at first sight seems to be some sort of 'flying saucer'. I could quite easily send it to one of our 'sensational' newspapers accompanied by a blurb incorporating the vital UFO-story phrases – *'loud noise'...... 'moving with terrific speed'...... 'gave off radiation'* etc. and accept a cheque instead. But it would be a hoax. Although the photo is a direct print from the negative (i.e. there has been no tampering during printing) the object is, in fact, the top half of a jam-pot *slightly out of focus. This gives the impression that it is moving about its y-axis.*

Anyone with *a camera and a jam-pot can photograph their own flying saucers.*

ROGER WHITNEY

Book Review

A small but confusing error crept into my book review published in March *Spaceflight* and it is ironic that it concerns a mistake involving a Roman numeral, since this was one of the subjects of my last letter to you.

In the heading of my review I put a Roman seven thus: 'vii', indicating that the book has 7 preliminary pages numbered in Roman as well as the main sequence numbered in Arabic from 1 to 534; this is library cataloguing practise. This has been mistaken for 'Vol. II' in the published review; the reviewed work has of course only one volume. I would be grateful if you would put the record straight.

Also, in the 6th paragraph, the reference to p.46 should be p. 469.

RAYMOND WARD

The Legendary 'Space Drive'

After a lifetime of experimentation the legendary 'Space Drive' has now, to me, come to stay.

I am starting to build a frame in which a special centrifuge gives lift to form a popular aerial runabout, for persons, whether motorised or pedalled.

The lift comes from directed forces within the centrifuge. The costs of space experiments are out of the question, but if the BIS produces an inexpensive light aluminium ball or cabin with oxygen, there is no reason why trips of 60 miles up to the atmosphere-space boundary should not be a regular occurence.

DAN LOGAN

(No thanks! –Ed.)

T 22

SATELLITE DIGEST — 65

A monthly listing of all known artificial satellites and spacecraft, compiled by Geoffrey Falworth. Information is based on that supplied by the Space Department of the Royal Aircraft Establishment, Farnborough, NASA, Satellite News and BIS sources. For information on the derivation of orbital parameters, abbreviations, etc., see July 1972 issue p. 262.

Continued from November issue, p. 433

Name, designation and catalogue number	Launch date, lifetime and descent date	Shape and weight (kg)	Size (m)	Perigee height (km)	Apogee height (km)	Orbital inclination (deg.)	Nodal period (min)	Launch centre, launch vehicle and payload/launch origin
Cosmos 562 1973-35A 6665	1973 Jun 5.48 6 months	Ellipsoid 400?	1.8 long? 1.2 dia?	270	487	70.98	92.13	Plesetsk Cosmos USSR/USSR
Cosmos 563 1973-36A 6667	1973 Jun 6.48 11.72 days (R) 1973 Jun 18.20	Sphere-cylinder 4000?	5 long? 2.44 dia	206 177	298 291	65.40 65.40	89.53 89.17	Plesetsk USSR/USSR(1)
1973-36D 6703	1973 Jun 6.48 19 days 1973 Jun 25	Sphere?	2 dia?	171	296	65.41	89.16	Plesetsk USSR/USSR(2)
Cosmos 564 1973-37A 6675	1973 Jun 8.65 8000 years	Ellipsoid 40?	1.0 long? 0.8 dia?	1395	1484	74.03	114.68	Plesetsk USSR/USSR(3)
Cosmos 565 1973-37B 6676	1973 Jun 8.65 9000 years	Ellipsoid 40?	1.0 long? 0.8 dia?	1450	1492	74.01	115.36	Plesetsk USSR/USSR
Cosmos 566 1973-37C 6677	1973 Jun 8.65 9000 years	Ellipsoid 40?	1.0 long? 0.8 dia?	1435	1486	74.01	115.12	Plesetsk USSR/USSR
Cosmos 567 1973-37D 6678	1973 Jun 8.65 9000 years	Ellipsoid 40?	1.0 long? 0.8 dia?	1414	1486	74.01	114.88	Plesetsk USSR/USSR
Cosmos 568 1973-37E 6679	1973 Jun 8.65 8000 years	Ellipsoid 40?	1.0 long? 0.8 dia?	1378	1482	74.02	114.43	Plesetsk USSR/USSR
Cosmos 569 1973-37F 6680	1973 Jun 8.65 7000 years	Ellipsoid 40?	1.0 long? 0.8 dia?	1359	1482	74.02	114.23	Plesetsk USSR/USSR
Cosmos 570 1973-37G 6681	1973 Jun 8.65 6000 years	Ellipsoid 40?	1.0 long? 0.8 dia?	1341	1481	74.02	114.03	Plesetsk USSR/USSR
Cosmos 571 1973-37H 6682	1973 Jun 8.65 6000 years	Ellipsoid 40?	1.0 long? 0.8 dia?	1321	1481	74.03	113.81	Plesetsk USSR/USSR
Cosmos 572 1973-38A 6684	1973 Jun 10.43 12.86 days (R) 1973 Jun 23.29	Sphere-cylinder 4000?	5 long? 2.44 dia?	206 174	281 271	51.66 51.64	89.32 88.89	Tyuratam-Baikonur USSR/USSR(4)
1973-38C 6711	1973 Jun 10.43 16 days 1973 Jun 26	Sphere?	2 dia?	171	280	51.65	88.95	Tyuratam-Baikonur USSR/USSR(5)
Explorer 49 1973-39A 6686	1973 Jun 10.59 Indefinite	Cylinder + 8 booms + 4 panels 200.49	0.79 long 0.92 dia	Selenocentric orbit				ETR LC 17B Delta NASA/NASA(6)
1973-40A 6691	1973 Jun 12.40 10^6 years	Cone-cylinder + 4 panels 907.25	6 long? 2.5 dia?	297 35533	35839 35901	26.33 0.53	633.0 1431.9	ETR LC 40 Titan 3C DoD/USAF
Titan 3C-19 1973-40B	1973 Jun 12.40 10^6 years	Cylinder 1500?	4.57 long 3.05 dia	297 35533	35839 35901	26.33 0.53	633.0 1431.9	ETR LC 40 Titan 3C DoD/USAF

Name, designation and catalogue number	Launch date, lifetime and descent date	Shape and weight (kg)	Size (m)	Perigee height (km)	Apogee height (km)	Orbital inclination (deg.)	Nodal period (min)	Launch centre, launch vehicle and payload/launch origin
Cosmos 573 1973-31A 6652	1973 Jun 15.25 2.0 days (R) 1973 Jun 17.3	Sphere-cylinder + domed cylinder + 2 panels + boom + antenna 6565?	7.5 long 2.2 dia	192	309	51.58	89.46	Tyuratam-Baikonur USSR/USSR
Cosmos 574 1973-42A 6707	1973 Jun 20.26 1400 years	Cylinder + boom?	1.4 long? 2.0 dia?	985	1014	82.94	105.14	Plesetsk USSR/USSR
Cosmos 575 1973-43A 6709	1973 Jun 21.56 11.71 days (R) 1973 Jul 3.27	Sphere-cylinder 4000?	5 long? 2.44 dia	204	271	65.41	89.25	Plesetsk USSR/USSR
Cosmos 576 1973-44A 6713	1973 Jun 27.50 11.79 days (R) 1973 Jul 9.29	Sphere-cylinder 4000?	5 long? 2.44 dia	204	332	72.86	89.88	Plesetsk USSR/USSR
1973-44H 6721	1973 Jun 27.50 17 days 1973 Jul 14	Sphere?	2 dia?	212	478	72.90	91.42	Plesetsk USSR/USSR

Supplementary Notes:

(1) Orbital data at 1973 Jun 7.0 and Jun 8.6.

(2) Ejected from 1973-36A during 1973 Jun 17.

(3) Sixth Soviet eight-payload satellite launch, 13th Cosmos multiple-payload mission and 16th Soviet multiple-satellite flight.

(4) Orbital data at 1973 Jun 10.6 and Jun 15.0

(5) Ejected from 1973-38A during 1973 Jun 22.

(6) RAE B is second in a series of radio astronomy Explorer satellites, first radio astronomy satellite to orbit Moon and second selenocentric Explorer spacecraft. Explorer 49, similar to Explorer 38 (1968-55A) measures galactic and extragalactic radio emissions, low-frequency solar radio bursts, sporadic jovian radio radiation, Earth's magnetospheric radio emissions and discrete radio sources in the 0.02-MHz to 13-MHz frequency range. Explorer 49's basic cylindrical magnesium and aluminium structure and outer aluminium honeycomb covering holds four boom-mounted solar cell arrays, 26°.5-canted, each holding 3520 negative-on-positive silicon solar cells providing average 38.5 watts power to an onboard six ampere hours-capacity nickel cadmium battery system, a 79.38-kg, 0.46-metre diameter, spherical rocket motor with its 6.35-kg, 0.46-metre diameter adapter disc mounted on top of the spacecraft structure, cylindrical liquid-fuelled velocity control propulsion system package using hydrazine fuel and a thruster system containing a catalyst for selenocentric orbit refinement and circularisation after orbital insertion and prior to being jettisoned into a selenocentric orbit on ground command, mounted below the spacecraft's main structure, four highly-polished, silver-plated beryllium-copper alloy 228.60-metres long, 5.08-cm wide, 0.002-cm thick reeled-tape antennae, internally stored on motor driven wheels prior to deployment following selenocentric orbit insertion, two mounted on top and two at the base of Explorer 49's cylindrical structure, two spacecraft midsection-mounted dipole antennae forming a 35.48-metres long antennae system, four turnstile telemetry antennae at Explorer 49's base, and two oppositely-mounted 96.01-metres long boron filament libration damper booms deployed on ground command from the spacecraft's base and top after selenocentric orbit insertion. Explorer 49's scientific investigations include precise observation and mapping of galactic low frequency radio radiation in studies of galactic structure and dynamics, observations of intense high-frequency radio emissions during solar storms including decrease in radio frequency of high-energy electrons spiralling along solar magnetic field lines towards Earth, attempted detection of radio noise and radio bursts from Jupiter for correlation with ground-based higher-frequency radio observations, acquisition of data on electromagnetic radiation from Earth's magnetosphere during spacecraft transits over lunar farside in shadow of Earth-emitted radio radiation, detection and measurement of low-frequency small discrete radio sources associated with Cygnus A and Centaurus A and measurement of intense sporadic magnetospheric radio emission. Explorer 49 antenna boom thermal control is maintained by internal black heat-absorbent coating and exterior silver finish and boom perforations reflecting and dissipating heat. Two slow-scan, 13 second-per-frame, spacecraft solar panel-mounted facsimile TV cameras, each using two 1.27-cm vidicon tubes and having 70°-to 360°-fields of view permitting both search and sector scan mode operation, search mode data being telemetered to ground stations in real-time as required, and associated lens assemblies and electronics, monitor both outwardly – and inwardly – oriented booms which carry white, tip-mounted, 13-cm diameter spheres for alignment and visual determination of radio source location. Onboard electronics and receiving systems acquire signals from each of Explorer 49's antennae, each receiver being tuned automatically. Antennae are disconnected each 10 minutes from their respective primary instrumentation and calibrated for 30 sec, the 228.60-metres long antennae being connected to an impedance probe and the 35.48-metre long dipole antennae being connected to a capacitance probe to measure inherent antennae properties in support of experiment data analysis. Scientific and engineering data are transmitted either in real-time or recorded by Explorer 49's two onboard three-track tape recorders each having a 225-minute recording capacity and a 45-minutes long playback time. Overall control of antennae and boom deployment, experiment activation, antennae TV target monitoring, real-time spacecraft status and ground commands is by Radio Astronomy Explorer Control Center at NASA's Goddard Space Flight Center which also receives tracking and telemetry data transmitted by the spacecraft at 136.860 MHz at 6 watts, backup telemetry at 400.959 MHz at 3.6 watts, range and range-rate tracking data at 136.145 MHz at 1.2 watts and 135.575 MHz at 1.2 watts acquired by NASA's Space Tracking and Data Acquisition Network stations. Explorer 49's attitude control system incorporates a solar aspect sensor measuring spacecraft-Sun angles and panoramic attitude sensors, using two fixed-plane scanning sensors operating during satellite spin mode and during operational gravity gradient stabilisation mode measuring angles between spacecraft and Sun, Moon and Earth; orientation data and ground commands activate Freon gas jets for spacecraft orientation and changes in satellite spin-rate.

SPACE REPORT

A regular monthly review of Space Events and Technical Trends

SKYLAB RESEARCH TRIUMPH

The second crew of Skylab astronauts, who have lived continuously in space longer than any other humans, collected more research information than mission planners expected and have exceeded the research goals set for them, writes Walter Froelich. The reasons for the favourable results are that equipment, after a series of annoying malfunctions, has been performing at and sometimes above design specifications, and that the crew's 'learning curve' on how to live and work in weightlessness reached a high-level sooner than flight directors expected. Not only is this likely to advance space flight in the future, but it is bound to provide scientists and engineers with many of the technological raw materials they need to solve some of mankind's most pressing problems.

Knowledge obtained through the Skylab project is expected to help raise living standards through new ways of producing electricity more cheaply and abundantly, treating diseases and maintaining better health because of a greater understanding of the human system, and providing more effective stewardship of the Earth and its resources through geological, meteorological and other studies.

The crew – Alan L. Bean, Commander; Owen K. Garriott, Ph.D., Science Pilot, and Jack R. Lousma, Pilot – attained the world's endurance record for manned space flight on 25 August when their stay in space passed the length of the flight of the first Skylab crew of 28 days and 50 minutes.

The first crew of astronauts – Charles Conrad, Jr., Jospeh P. Kerwin, M.D., and Paul J. Weitz – overcame even more serious equipment failures than the second crew, but completed about 80% of the assigned research tasks.

That crew returned to Earth on 22 June with scientific and technological research data, on films, magnetic tape and in specimen containers, weighing more than the entire Mercury capsule (including astronaut) in which John H. Glenn became the first American to orbit the Earth in 1962.

The second crew, passed the halfway point of its mission on 26 August, and began its unprecedented second month in space shortly after 1200 GMT on 28 August.

A third crew, now in training, is to be launched at Cape Kennedy, Florida, on 9 November for a stay inside Skylab of 56 days until 4 January 1974.

How efficiently some of the Skylab equipment is operating is exemplified by Skylab's remaining wing covered with solar cells which convert sunshine to electricity for Skylab's use. One wing was torn off accidentally during launch and the remaining one was jammed by debris so that it failed to unfold in orbit until astronauts Conrad and Kerwin loosened it during a spacewalk and repair expedition outside Skylab on 7 June. Since then, the wing, designed to generate 6,200 watts, has been supplying between 6,500 and 7,500 watts depending on Sun angles and temperature conditions.

Successful repair work has also been accomplished by the second crew during two of three planned spacewalks. While unfavourable cloud conditions forced the crew to suspend many of its planned Earth resources observation experiments in the second half of August, the astronauts worked with their Sun telescope system 6 to 7 hours daily, exceeding by far the solar astronomy tasks assigned to them.

Similarily, the crew was ahead of schedule on its various technological experiments including those suggested by high school students. One of these experiments observed how well a spider can spin a web in weightlessness. After repeated failures the spider adapted to work in the space environment and successfully spun a nearly perfect web.

In spite of the adverse atmospheric conditions, the crew has completed more than a third of its 26 Earth resources photography assignments, including passes over Southeast Asia and Australia. The crew was fully up to date on medical experiments which followed a strict agenda.

During their first several days in space following launch on 28 July, the three astronauts felt distressed by motion sickness which slowed and at times briefly halted their work. Once the men recovered, however, they showed unexpectedly quick adaptability to the space environment. The men have learned how to walk, float and manoeuvre themselves in the 12,607-cubic feet interior of Skylab, and how to work, eat and sleep there free from the customary pull of gravity.

Skylab planners made allowances in designing crew activities for a learning period after a crew's arrival at the space station and also for the possibility that occasional equipment problems might delay procedures. The second Skylab crew required less of a margin for their learning and their equipment problems than was provided for in their flight plan.

FOUNDATIONS OF SPACE MEDICINE

The USSR Academy of Sciences and NASA have approved the report of the fifth meeting of the US/USSR Joint Editorial Board which is preparing the publication, 'Foundations of Space Biology and Medicine'. The Board met in Moscow on 7-15 June 1973.

At the meeting, the Joint Editorial Board agreed on schedules for preparation and completion of the three-volume publication. It is planned to complete the publication of the first volume on 1 May 1974 and the second and third volumes by 1 July 1974.

Most chapter manuscripts have been submitted by their authors and the exchange of manuscripts between the two countries is progressing satisfactorily.

Presiding at the meeting were Professor Oleg G. Gazenko, of the Soviet Academy of Sciences, co-chairman of the Editorial Board, and Dr. Orr E. Reynolds, acting US co-chairman, American Physiological Society, in the absence of the US co-chairman, Professor Melvin Calvin, University of California.

EARTH RESOURCES FROM SHUTTLE

A contract to study future Earth resources systems from the acquisition of data to their eventual application by city planners, conservationists, pollution control officials, oceanographers, farmers and countless other users, has been awarded to General Electric's Valley Forge Space Center of Philadelphia, Pennsylvania.

During a year of study, analysts from General Electric will establish detailed guidlines to assist the Earth Resources Program Office at NASA's Johnson Space Center in planning projects to be instituted at the end of the decade. These guidelines will include unique contributions to be made by the Space Shuttle in surveying the Earth's resources. The study will focus on hardware and procedures to be developed during the coming years.

General Electric will provide an analysis of the best use of aircraft, unmanned satellites, and the Space Shuttle in performing a variety of Earth observation projects. Such detailed

investigations of alternatives will be of considerable use in developing a balanced programme for surveying the Earth's resources at the lowest possible cost.

Areas to be considered by General Electric researchers during the coming year include remote sensing instrumentation, aircraft, unmanned spacecraft, manned modules, Shuttle experiment pallets, data processing requirements, data analysis techniques, data handling systems, and the active utilization of information acquired by the appropriate user agencies.

By preparing such a study several years in advance, NASA planners can assure that the required equipment will be developed and tested in time for use at the end of the decade, and that the data provided can be handled quickly and converted into useful forms at the lowest possible cost.

Earth resources projects are expected to be among the most valuable applications of the Space Shuttle, which will launch automated satellites as well as carrying scientists and sensing instruments for up to 30 days in orbit.

The cost-plus-fixed-fee contract with General Electric calls for total expenditures of $234,788 over a 12-month period.

HEAO PROGRAMME

Under the scaled-down programme, three spacecraft will be launched by the smaller Atlas-Centaur rocket between 1977 and 1979. Plans call for additional launches from the Space Shuttle, starting about 1980.

Because of the smaller Atlas/Centaur, the planned HEAO is capable of supporting about 2,800 lb. of scientific instruments. The rocket's shroud limits the length of the observatory to about 12 ft. with a diameter of 9 ft.

Initial scientific emphasis will be on X-ray astronomy. Present plans call for the first mission to perform an X-ray survey, the second detailed X-ray studies, and the third, a gamma-ray and cosmic ray survey of the sky. Later launches from the Space Shuttle would carry the heavier gamma ray cosmic ray experiments, thus completing the HEAO scientific objectives.

Three scientific payloads, selected by NASA from among the original experiments, are under study by TRW Systems at Redondo Beach, California, the prime contractor, and plans for a reduced HEAO Programme have been reviewed and endorsed by the Space Science Board and its Committee on Space Astronomy. Whereas the estimated cost of the original HEAO programme was $275 million, the revised programme is expected to reduce this by about half.

Management of the HEAO programme will remain at the Marshall Space Flight Center, Huntsville, Alabama. During the period of suspension, Marshall has been studying ways of achieving many of the objectives of the original programme at reduced cost.

REMOTE SENSING SOCIETY

A Remote Sensing Society with the aim of advancing the various aspects of remote sensing will come into formal existence in the United Kingdom on 1 January 1974. We welcome this new initiative which stems from a body of scientists, technologists and administrators deeply interested in methods of measuring and managing the Earth's resources and environment. In areas where interests overlap – particularly in the technology of Earth Resources satellites – there should be much scope for cooperation with our own Society.

The objectives and aims of the Remote Sensing Society are the general advancement of aspects of remote sensing. Principally, this is to be taken as referring to remote sensing of the Earth and its environment by observations from airborne and spaceborne platforms.

Although formed in the United Kingdom, it is the intention of the Council that the Remote Sensing Society will be international in concept and character. Two technical sessions are to be held early in 1974, the theme of the first session being: 'Fundamentals of Remote Sensing'. This will be held in London in February 1974. The second session will be held at the University of Sheffield on 14 April 1974, with the theme: 'Applications of Remote Sensing - data processing and analysis'.

Information on the aims of the Remote Sensing Society, on the various General Meetings and Technical Sessions, together with details of membership, can be obtained from the General Secretary, Dr. W. G. Collins, Department of Civil Engineering, University of Aston, Birmingham, B4 7ET, England.

SPACE SHUTTLE TANK

A contract for the design, development, test and evaluation of the external tank for the Space Shuttle has been awarded to the Martin-Marietta Corporation, Denver Division.

The cost-plus-award-fee contract, which extends into 1978, includes the fabrication of three ground test tanks and six developmental flight tanks. The contractor's proposed cost is $107 million.

Four firms submitted proposals to the Marshall Space Flight Center for this work: Chrysler Corporation, Space Division, New Orleans; Martin-Marietta Corporation, Denver, Colorado; McDonnell-Douglas Astronautics Company, Huntington Beach, California; and the Boeing Company, New Orleans.

Tank assembly will be at the NASA Michoud Assembly Facility in New Orleans, a part of MSFC. The external tank will carry liquid oxygen and liquid hydrogen – a total of 675,000 kg (1.5 million pounds) – to feed the three main engines on the shuttle orbiter. It will be 8.1 metres (27 ft.) in diameter and 57.4 metres (158 ft.) long.

MARS PROBES ON TARGET

The four Soviet space probes scheduled to rendezvous with Mars between mid-February and mid-March have been sending back miles of taped data on cosmic rays, solar 'noise' in the metre waveband and registering the fluxes of solar flares.

The probes – Mars 4, 5, 6 and 7 – have a very heavy programme of research on Mars itself, according to Academician Roald Sagdeyev, director of the USSR's Space Research Institute. Landings are planned with the object of 'discovering the physical characteristics of the ground and surface rocks'. Attempts will also be made to obtain TV pictures of the surrounding area.

From orbit, a main task will be to photograph the planet's surface. Study will also be made of gravitational and magnetic fields, atmosphere, temperature and surface relief.

BOOK REVIEWS

Edited by L. J. Carter, ACIS, FBIS.

Mars
By Patrick Moore and Charles A. Cross, Mitchell Beazley, pp. 48, 1973, £4.85.

Of the innumerable astonishing accomplishments of spacecraft technology over the past 15 years, surely one of the most outstanding is the phenomenally successful close-range photography of Mars by Mariner 9, and it is on the basis of these photographs that Charles Cross has produced his excellent topographic maps of the Martian surface. These are presented in 4 quadrants between 60°N and 60°S (on Mercator projection) and two polar charts (on stereographic projection). These maps are accurate to within 60 km.

Although quite a number of photographs are reproduced, I think rather more could have been printed – after all, the book (intended as a guide to Mars) is only 48 pages in length, and Mariner 9 took over 7000 photographs! (Strangely enough, a colour picture of the launch of Mariner appears twice in the text).

There is a rather rudimentary introduction to Mars written by the two authors, but some fine colour photographs of Mars taken by Earth-based telescopes. The text on topography and explanatory notes accompanying the maps and photographs are minimal, even padded out, and certainly no topic is dealt with in detail. There is little attempt at interpretation – perhaps this is fortunate, since this should be left to the experts. In any case, the book is strictly for the layman (it has an appearance not unlike a children's encyclopaedia). The text is often misleading, even inaccurate. I also suspect that certain textual directions, designed to help the reader find features on the charts, are misorientated.

There is a penultimate section devoted to Mars' satellites, with several photographs taken by Mariner 9. With some amusement (and not a little inaccuracy) it is stated that from the surface of Mars the tiny Phobos would exhibit an apparent diameter ranging from 12°.3 to 7°.9 (*'less than half the apparent diameter of the Moon as seen from Earth'* (sic) – good news for lunar observers!), and the even smaller Deimos would be seen to have the incredible range 2′ to 1°.7!! (It need hardly be said that all units should be arcminutes).

The introduction says that this atlas of Mars *'is comparable with atlases of the Moon'* – how modest!

S. G. SYKES

Beyond Jupiter, The Worlds of tomorrow
Text by Arthur C. Clarke and paintings by Chesley Bonestell, Little, Brown and Co., (Boston, Mass. 1973) $12.95.

A pedigree of Clarke out of Bonestell could hardly fail to produce a winner. Nevertheless, as for any thoroughbred, the purchase price is expensive. It can be read in two hours and the 62 pages of text, for artistic reasons, are only half-filled with print. To these we must add 3 pages of diagrams, 21 pages of black-and-white photographs and drawings, and 16 pages of full-colour reproductions of Chesley Bonestell's works. Doubtless these are responsible for the high price.

The book is beautifully produced and contains very few typographical errors. Figs. 3, 4 and 5 have unfortunately been printed as Figs. 4, 5 and 3 with a consequent shuffling of captions. On p. 37, the 'yards of recording paper with hen tracks' conjures up visions of a poultry-infested control room at JPL. The omission of an index in a work of this length is probably not serious.

The first chapter reviews progress to date and sets the scene for the Grand Tour missions later this decade, even though 'for NASA, the Grand Tour has, alas, become the Economy Tour'. Always the master of the analogy, Clarke refers to the space-shuttle as 'the DC-3 of astronautics. Or, at least, the DC-1.....' and is prepared to borrow from astronaut, David Scott, the parallel with the history of Antarctic exploration to describe the present lull following the close of the first phase of lunar exploration. However, Clarke does not foresee a 50-year hiatus this time.

Chapter 2 deals non-mathematically with the celestial mechanics of the Grand Tour. The explanation of the way in which a spacecraft can gain energy from a gravity-assisted planetary encounter, based on Maxwell W. Hunter's analogy of the perfectly elastic barrier,is particularly good. The reinforcement of the argument by reference to the game of tennis is an illustration I shall unashamedly adopt for my own teaching notes. After dealing with 'windows' and how they arise, the author points out that the Grand Tour is possible with existing launch vehicles such as Atlas-Centaur and Titan.

In the third chapter we read about the exploration of the Moon and Venus with robot probes and we see three Ranger 9 photographs as it approached the Moon and the classic Lunar Orbiter 2 photograph of the crater Copernicus. The next chapter turns to Mars and provides an eye-witness account of the scene in the Jet Propulsion Laboratory, Pasadena, at the time of the insertion of Mariner 9 into Aerocentric orbit and the subsequent reception of pictures. Here one will find mention of bit-rate, transmission time, received power, 'computer-enhancement', etc. in sufficient detail for the non-specialist.

We now move into the future and here Bonestell's work takes over and comes into its own. Chapter 5 deals with the 1973 Mariner Venus-Mercury mission which, by the time this review appears, may already be under way. The descriptions of the planets are continued in subsequent chapters which also take in asteroids and comets and the mysteries of RTG's, TOPS, STAR and TARP.

I always look for an element of prophesy in any work of Arthur C. Clarke,and for this one turn to the final chapter. But this I will leave to you..........expensive or not, this is one not to be missed.

G. E. PERRY

Search The Solar System
By J. Strong, David and Charles, pp. 160, 1973, £3.25.

Before manned flights to the planets can even be contemplated, a great deal of scientific information about the many planets and satellites in the Solar System will have to be gathered by unmanned planetary spacecraft. This book describes not only what has been achieved to date by such probes, but also what imaginative ventures might be attempted in the future.

Several chapters consider some of the constraints to which planetary probes are subject, in terms of propulsion, instrumentation and communication requirements. The special problems that planetary roving vehicles will face are also mentioned, e.g. the finite time-delay between transmission of a radio signal from Earth and its reception by a roving vehicle could prove disastrous for the vehicle.

Brief details of the results from the various American and Russian fly-by, orbiting and landing spacecraft to Venus and Mars are given although the instrumentation used to obtain the data is not described. Should visual photography of Venus prove impossible because of the clouds then the author feels

that an orbiting radar satellite might be used to map the Venerian surface, and neutral buoyancy balloons could gather data from various levels in the atmosphere.

Other sections consider such missions as probes to Mercury and the Sun, (the 'kamikaze' craft which gathers its solar data in the last few seconds before it is destroyed is particularly ingenious); probes to the Asteroid belt, Jupiter and its moons, Saturn and its rings; and probes to intercept comets, especially Halley's comet on its return in 1986. The Grand Tour missions to the outer planets are also reviewed, despite their cancellation by NASA, since it is quite possible that the Russians will attempt such a project.

The author also describes how the present problem of discontinuous communications with planetary spacecraft could be overcome in the future by the use of 'Trojan relay' communication satellites. If such satellites are placed at the 2 stable Lagrangian points in the Earth's orbit and any planet's orbit, then not only can one ground station have 24 hour communication with a probe, but continuous contact can be maintained with a roving vehicle even when it is on the side of a planet facing away from the Earth.

This book provides a good, easily understandable introduction to the potentialities of unmanned interplanetary probes and it will be of particular interest to the layman because of its non-technical, descriptive approach.

RICHARD JAHN.

The Planets – Some Myths and Realities
By R. Baum, David and Charles, pp. 200, 1973, £3.50.

Observational astronomy is one of those sciences in which the skill of the individual is of paramount importance. However, even the most experienced observer can occasionally make a mistake, or imagine he sees something that does not in fact exist, and this can lead to some unusual and curious observations finding their place in astronomical records. Richard Baum has taken eight such mysteries and written them up as complete case histories.

The first chapter relates the history of various photographic searches from 1888 onwards for small, natural satellites of the Moon. The most recent search was conducted by Tombaugh in 1956 since it was feared that any unknown lunar satellites could be hazardous to future manned missions to the Moon. However, Tombaugh discovered no object bigger than his resolution limit of a few tens of yards.

Only in the past few years has the puzzle as to what lies beneath the dense, inpenetrable cloud cover of Venus been partially answered by planetary spacecraft. In the eighteenth century, some eminent astronomers – notably Schröter – believed that the irregularities seen in the Vernerian terminator were due to mountains protruding through the clouds. Schröter even went so far as to calculate the height of these 'Himalayas of Venus', and he estimated them to be about 23 miles high! Such mountains were soon shown to be absolutely impossible simply because they would temd to collapse under their own weight! Curiously though, recent developments in radar astronomy have shown that there are two regions on Venus that are probably mountain ranges.

Perhaps the most interesting mystery considered is the one entitled 'Strange Interlude'. This illustrates that not even published scientific data should be taken at face value. During 1850, Hind tracked a minor planet and referred its position on one night to a nearby star which was later found to have 'disappeared'. However, it was subsequently shown by Peters that the star's position had been wrongly reported due to Hind's misreading of a micrometer! On re-checking his original records, Hind found that this was what had indeed occurred.

Other chapters review the history of observations of the 'rings' of Uranus and Neptune, and various star-like objects that were never seen again.

The book is well-written, with several good plates and numerous quotes from original sources. It is just the book for amateur astronomers to read on cloudy nights.

RICHARD JAHN

'The Solar System'
By Z. Kopal, Oxford University Press. pp. 152, 1973, £2.25. (Also in Paperback £1.00.).

Although an admirer of Professor Kopal's work for many years, I feel that this latest book just misses the target. Indeed, it is difficult to define the class of reader for whom it is intended. A mass of facts is crammed into a text of high academic standard, which together with some mediocre illustrations, make it only slightly more readable than the *'Astronomical Ephemeris'*. This is in spite of the relatively few and easily assimilated formulae for which no derivations are given, completely nullifying its use to advanced students as anything but a supplement to other basic sources.

The author himself admits that emphasis is laid on the most recent work with data mostly from space probes, and I was pleased to see metric values used throughout. As he also points out, a description of our parent luminary is missing, so one feels that perhaps a more appropriate title might have been 'Latest Developments in Planetary Research'.

In a book of this kind it is usual to take each planet in turn and devote a chapter to it, but Kopal classes his planets according to size and composition; the major planets and their satellites, the Earth, Venus, Mars etc. Poor Mercury and Pluto merit three pages between them, much less than a description of meteors and interplanetary dust. Of course, until we obtain probe data from these bodies, we can expect little advancement of our knowledge, but I feel that a somewhat unbalanced view is presented. The chapter on the Moon is separated from that on the Earth by some thirty pages, which does not completely reflect contemporary ideas of a double planet system. In common with other parts of the book, the description of the Earth is shallow, though it does whet the appetite for collateral reading, a guide to various levels being given later on.

However, Kopal manages to instil some life into his final chapters on the structure and origin of our Solar System and other such systems in the Universe which were very interesting indeed, though it could be argued that, by eliminating the latter, better appreciations could have been made elsewhere.

By its statistical style, this is a book that will date quickly as measurements improve and better techniques are available, but it does outline our understanding of our neighbouring planets, A.D.1972. Unfortunately the many misprints are evidence of a rush to Press, that bane of scientific authors. The caption to Plate 12, must make Professor Kopal squirm, since it rather suggests the 'Eagle' landed at Tranquility Base a clear month before we all saw it happen on TV!

The book concludes with a Glossary and some suggestions for future reading, most of which are somewhat 'dated'.

A. M. NIXON.

Astronomical Telescopes and Observatories for Amateurs
Ed. Patrick Moore, David and Charles, pp. 256, 1973, £4.75.

Not unexpectedly, much of the material presented in this book has appeared elsewhere in the wealth of publications catering for the practical amateur astronomer. However, it is convenient to have this information in a single, easily digestible volume, especially from the viewpoint of the beginner.

There are chapters by 14 authors covering (in Part 1) most aspects of telescopes, their adjustments and maintainance, ancilliary equipment and (in Part 2) housings for such instruments. To both sections of the book there are introductory remarks by the Editor. There is plenty of practical guidance on refracting and reflecting telescopes for the tyro, by I. Nicolson and G. A. Hole, with sound advice from H. E. Dall on eyepieces, from T. Moseley on telescope mountings, and T. W. Rackham on mirror-making. H. R. Hatfield (well-known for his fine photographs of the Moon) presents a section on astronomical photography which will certainly be of value to the newcomer, whilst L. Wilson's contribution on elementary astronomical cinephotography will clearly be of very limited use.

The second part of the book deals with the construction of three types of telescope housing: from the simple run-off shed, and run-off roof observatories, to the more elaborate observatory domes, all of which are within the scope of the constructionally-minded amateur.

By and large, this book is written *by* amateurs *for* amateurs (and indeed the writing by a few authors may best be described as amateurish!). Although a little overlapping of sections is unavoidable, rather too much common territory is covered at times. Perhaps the price might have been less had there been *closer* collaboration between *fewer* contributors, and rather more stringent editing. Certainly Colin Ronan's chapter on the history of large professional telescopes (including radio telescopes!), interesting though it may be, seems largely superfluous in a practical book such as this. Notwithstanding, this book should help the beginner to decide which type of telescope and observatory best suits his requirements.

The text is relatively free from errors, although Fig. 36 illustrating J. C. D. Marsh's 'simple photometer' is even simpler than he intended – it lacks the all-important comparison light source in the circuit diagram!

S. G. SYKES.

Astronautics and Aeronautics, 1970: Chronology on Science Technology, and Policy
By Science and Technology Division, Library of Congress, NASA, pp. 510, 1972, $2.75.

The sub-title is something of an understatement. Every aspect of the American aerospace programme, scientific, technical, industrial, social, political and economic is set down in crisp, no-nonsense form. Russia, Europe, and other 'interested parties' receive coverage commensurate with their level of aerospace activity.

Just about everything that went up (or came down) during 1970 is duly noted. Every launching, manned or unmanned, is recorded, giving lift-off time, orbital details, description of payload where available. There are many guarded references to 'unidentified' satellites launched by the USAF, and information on some Russian satellites is sketchy.

Considerable space is devoted to the behind-the-scenes political wrangling, particularly over finance, and the comments of newspapers of varying persuasions.

The 'big story' is the near-tragic Apollo 13 mission, related in clipped phrases that convey little of the tension during those perilous hours, or the heartfelt relief when the crew stepped unharmed aboard the recovery ship. Only the cold facts are given. It is left to quotes from newspaper reports to convey the emotions.

Russia's Soyuz 9 mission is adequately covered, as is the landing on the Moon of Luna 17, to disgorge Lunokhod 1.

Besides purely technical data, there are items concerning the people behind the aerospace programme. Goodwill tours of astronauts and cosmonauts, appointments, resignations, the doings of former astronauts, also the cheers and smears from various press and political commentators.

Mention is made of preliminary planning for projects that are now accomplished fact, or nearly so, Skylab and the Space Shuttle; also the eternal squabbling over whether money should be spent on space research or 'safeguarding the environment'.

Many interesting and amusing snippets are slipped in: minor spin-offs from the space programme, such as the sale of rubber rafts as used by astronauts; the 'bugging' of an elk so that its migration could be traced by satellite; attempted sale of phoney 'moon rock' in Frankfurt; a lawsuit brought by an athiest lady to ban the broadcast of prayers by astronauts in space; even UFO's are not forgotten.

The text is backed by a comprehensive index cum glossary of abbreviations and acronyms, with a separate list of abbreviations used by the compilers. The source of every entry is quoted, and cross referenced where applicable. Measurements are metric, with English equivalents in parenthesis.

A veritable mine of information, easy to dig into; excellent value for money!

G. W. BRUNT.

Interplanetary Flight and Communication
Vol. 1 No. 1, N.A.Rynin, NASA TT F-640, pp. 113, 1970, U.S. Dept of Commerce.

This Israeli translation is of the 1st volume of Rynin's projected 10 part astronautical encyclopaedia which first appeared in Leningrad from 1928 to 1932.

Despite its title *'Dreams Legends and Early Fantasies'* this volume has something for those who want information on the state of the art in the 1920's. Rynin starts soberly by examining the problems involved in a manned flight between two celestial bodies. Then he surveys the most advanced thinking of his day: from topics such as interplanetary thought transference, to optical phenomena as near-light speeds, use of Earth-Moon Lagrange points, and orbital rendezvous landings on the planets. There is an account of the early space activities of the Air Force Academy of the USSR.

The rest of the work is concerned with legendary and literary references to celestial bodies. Some are well-known as they come from sources which have been assimilated into West-European culture. Less well known are traditional and modern Russian fairy stories, Indian legends, and the Finnish Kalevan epic poem. Chapters on forms of flight on supernatural beings, as in the *Koran*, and on flying horses, are followed by one on the design of imaginery spacecraft.

Rynin rarely acknowledges sources, either of text or illustrations. The lack of an index makes selective reading difficult.

T. F. MACKENZIE.